I N D E X

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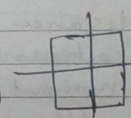
→ Failure Theories

① Max. principal stress theory (Rankine)

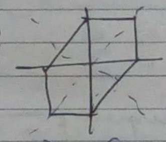
$$\boxed{\sigma = \frac{S_{ut}}{fos}}$$



ordinary cast iron & brittle materials

② max. shear stress theory (Guest/Tresca)

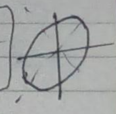
$$\boxed{\tau = \frac{\sigma}{2}}$$



safe results for ductile

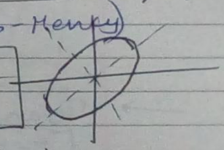
③ strain Energy theory (Haigh) (≈ ductile)

$$\boxed{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \frac{2}{m}(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = \sigma_e^2}$$



④ shear strain energy theory (Mises-Henky)

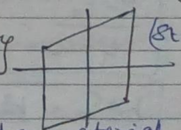
$$\boxed{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2 = 2\sigma_e^2}$$



best for ductile

⑤ max. principal strain theory (St-Venant)

$$\boxed{\sigma_1 - \frac{1}{m}(\sigma_2+\sigma_3) < \sigma_e}$$



brittle material

→ Strain energies

tension = $\boxed{\frac{\sigma^2}{2E} \times V}$

Shear = $\boxed{\frac{\tau^2}{2C} \times V}$

torsion = $\boxed{\frac{\tau^2}{4C} \times V}$

$$\boxed{\frac{\tau^2}{4C}\left(\frac{R^2+r^2}{R^2}\right)V}$$

→ Shearing Stresses

$$\boxed{\tau = \frac{SA\bar{y}}{Ib}}$$

S - shear force
A = cross-sectional area
$\bar{y}$ = distance from neutral section
I = moment of inertia
b = width of beam at point where shear force is considered.

Rectangular $\boxed{\tau_{max} = \frac{3}{2}\tau_{mean}}$

Solid circular $\boxed{\tau_{max} = \frac{4}{3}\tau_{mean}}$

→ Transient conduction

$$\boxed{\frac{t - t_a}{t_i - t_a} = e^{-\frac{hA\tau}{\rho VC}}}$$

$$\boxed{\frac{hA\tau}{\rho VC} = \left(\frac{hL_c}{K}\right)\left(\frac{\alpha\tau}{L_c^2}\right) = B_i F_o}$$

$Q = -hA(t_i - t_a)\,e^{-B_i F_o}$ — instantaneous heat transfer

$Q' = \rho VC(t_i - t_a)\left(e^{-B_i F_o} - 1\right)$ — total heat tranfer

Time constant $= \frac{\rho VC}{hA}$

Response time taken for temp. change to reach 36.8% of its final value.

Sensitivity - time taken for ~~temp~~ ΔT to be 63.8% of initial value

→ Radiation

Wien's disp. law $(E_b)_{max} = 1.285 \times 10^{-5}\, T^5 \ \frac{W}{m^2}$

$$\boxed{\lambda_m T = 2829}$$

→ Radiation Exchange b/w 2 non-black bodies

$$Q_1 = \frac{\varepsilon_1}{\frac{\varepsilon_1}{\varepsilon_2} + 1 - \varepsilon_1} \qquad Q_2 = \frac{\varepsilon_2}{\frac{\varepsilon_2}{\varepsilon_1} + 1 - \varepsilon_2}$$

interchange factor $f_{1-2} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$

parallel flat plates

$$\boxed{\text{parallel cylinders} \left(\frac{1}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2} - 1\right)}\right)}$$

→ Effectiveness of fin $= \boxed{\frac{Q_{\text{with fin}}}{Q_{\text{without fin}}}}$

→ Complex Numbers

$u + iv$ = Real + i(Imaginary)

De Moivre's Theorem $(\cos\theta + i\sin\theta)^n = \cos n\theta + i\sin n\theta$

$$\boxed{e^x = \sum_{i=0}^{\infty} \frac{x^i}{i!}}$$

Hyperbolic functions

$$\boxed{\sinh x = \frac{e^{x} - e^{-x}}{2}}$$

$$\boxed{\tanh x = \frac{\sinh x}{\cosh x}}$$

$$\boxed{\cosh x = \frac{e^{x} + e^{-x}}{2}}$$

$\sin(ix) = i\sinh x$
$\cos(ix) = \cosh x$
$\tan(ix) = i\tanh x$

$\sinh x = i\sin x$
$\cosh x = \cos x$
$\tanh ix = i\tanh x$

CR - conditions

$$\boxed{\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}} \qquad \boxed{\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}}$$

Cauchy's Theorem

if $f(z)$ is analytic in closed curve C,

$$\int_C f(z)dz = 0.$$

Cauchy's Integral Formula

$f(z)$ is analytic in closed curve C except at point a,

$$\boxed{f(a) = \frac{1}{2\pi i}\int \frac{f(z)}{z-a}\,dz}$$

$$\boxed{f^{n}(a) = \frac{n!}{2\pi i}\int \frac{f(z)}{(z-a)^{n+1}}\,dz}$$

Residue

coeff. of $\frac{1}{z-a}$ in expansion of $f(z)$ around isolated singularity is called residue

$$\text{Res} f(a) = \frac{1}{2\pi i}\int_C f(z)dz$$

$$\int_C f(z)dz = \int_{C_1} f(z)dz + \int_{C_2} f(z)dz + \cdots + \int_{C_n} f(z)dz$$

$$= 2\pi i\left[\text{Res} f(a_1) + \text{Res} f(a_2) + \cdots + \text{Res} f(a_n)\right]$$

$$\boxed{\text{Res} f(a) = \lim_{z\to a}\left[(z-a)f(z)\right]} \rightarrow \text{pole of order } 1$$

$$\boxed{\text{Res} f(a) = \frac{1}{(n-1)!}\left[\frac{d^{n-1}}{dz^{n-1}}\left[(z-a)^{n} f(z)\right]\right]_{z=a}}$$

→ Matrices

Sol^n of eqns. Homogeneous Equations

r = rank of coeff. matrix.
n = no. of coefficients.
$\Rightarrow r = n$, $x_i = 0$
$\Rightarrow r < n$ ∞ly many solutions

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→ **Series expansions**

$$\boxed{e^x = \sum_{i=0}^{\infty} \frac{x^i}{i!}}$$

$$\boxed{\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \cdots}$$

$$\boxed{\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \cdots}$$

$$\boxed{\log(x+1) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots}$$

$$\boxed{\text{Maclaurin series} = f(x) = f(0) + x f'(0) + \frac{x^2}{2!} f''(0) + \frac{x^3}{3!} f'''(0) + \cdots}$$

$$\boxed{\text{Taylor Series} = f(x+a) = f(a) + \frac{x}{1!} f'(a) + \frac{x^2}{2!} f''(a) + \frac{x^3}{3!} f'''(a) + \cdots}$$

→ **Bearings**

C_0 = static load carrying capacity $= \frac{K d^2 Z}{5}$

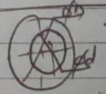
P = dynamic load $= XVF_r + YF_a$

L_{10} = life in million revolutions $= \left(\frac{C}{P}\right)^p$

$$\boxed{L_{10} = \left(\frac{C}{P}\right)^p = \frac{60 L_{10h} n}{10^6}}$$

$p = 3$ (ball brg)

$p = \frac{10}{3}$ (roller bearing)



$$\boxed{\text{Sommerfield } N_0 = \frac{\mu N}{p}\left(\frac{d}{c}\right)^2}$$

μ = viscosity, N = rpm

p = unit bearing pressure

d = dia of journal (inner circle)

c = clearance $= (D-d)$

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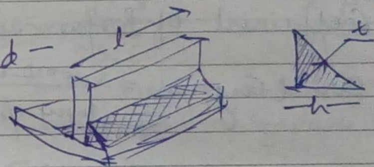
$$\boxed{P_e = \sqrt[3]{\frac{\Sigma N_i P_i^3}{\Sigma N_i}}} \qquad \frac{L}{L_{10}} = \boxed{\frac{\ln(1/R)}{\ln 1/R_{90}}}$$

→ **Welding**

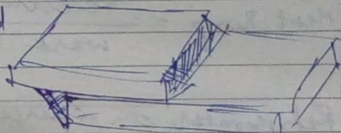
Parallel Fillet weld –

$P = 0.707 hl\tau$



Transverse fillet weld

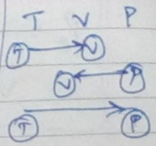
$P = 0.707 hl\sigma$



→ **Work done**

Process	Q	W	ΔS
$PV = C$	$P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$	$P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$	$R \ln\left(\frac{V_2}{V_1}\right)$
$PV^\gamma = C$	0	$\frac{P_1V_1 - P_2V_2}{\gamma - 1}$	0
$P/T = C$	$C_v \Delta T$	0	$C_v \ln \frac{T_2}{T_1}$
$V/T = C$	$C_p \Delta T$	$P\Delta V$	$C_p \ln (T_2/T_1)$
$PV^n = C$	$\frac{C_v(\gamma - n)}{1-n} \Delta T$	$\frac{P_1V_1 - P_2V_2}{n-1}$	$C_v \left(\frac{n-\gamma}{n-1}\right) \ln\left(\frac{T_2}{T_1}\right)$

$$\Delta S = C_v \ln T_2/T_1 + R \ln v_2/v_1$$
$$= C_v \ln P_2/P_1 + C_p \ln v_2/v_1$$
$$= C_p \ln T_2/T_1 - R \ln P_2/P_1$$



→ **Coefficient of Performance**

Carnot Engine $= \dfrac{\text{work output}}{\text{input from reservoir}}$

Heat Pump $= \dfrac{\text{reservoir heat}}{\text{work input}}$

Refrigerator $= \dfrac{\text{source heat}}{\text{work input}}$

→ **Clutches**

uniform pressure theory

$\boxed{R = \dfrac{2}{3}\left(\dfrac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right)}$ $\boxed{T = \mu W R}$

$\boxed{\text{pressure} = \dfrac{W}{\pi(r_1 - r_2)}}$

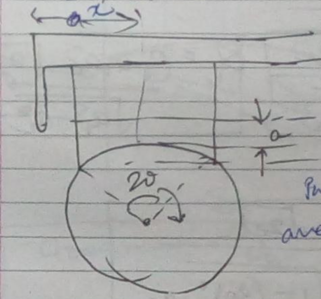
uniform wear theory

$\boxed{R = \dfrac{r_1 + r_2}{2}}$ $\boxed{T = \mu W R}$ $\boxed{\text{pressure} = \dfrac{W}{\pi(r_1^2 - r_2^2)}}$

cone clutch $\boxed{T = \dfrac{\mu W R}{\sin\alpha}}$

→ **Brakes**

Shoe brake



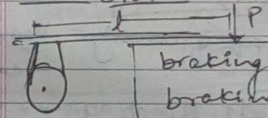
clockwise braking torque $T_B = \dfrac{\mu P l}{x - \mu a}$

$2\theta < 60^\circ$

Initial braking power $= T_B \times \omega$

average ~~power~~ braking power $= \dfrac{0 + T_B \times \omega}{2}$

Band Brake



braking force $= T_1 - T_2$

braking torque $= (T_1 - T_2) R$

Band & block brake

$$\frac{T_1}{T_2} = \frac{(1 + \mu \tan\theta)^n}{(1 - \mu \tan\theta)^n}$$

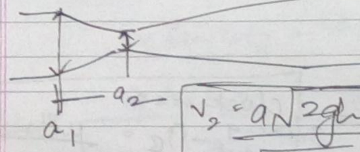
→ **Projectile motion**

$\boxed{\text{highest point} = \dfrac{u^2 \sin^2\alpha}{2g}}$ $\boxed{\text{Time of flight} = \dfrac{2u\sin\alpha}{g}}$

$\boxed{\text{Time taken to reach the highest point} = \dfrac{u\sin\alpha}{g}}$

$\boxed{\text{Range} = \dfrac{u^2 \sin 2\alpha}{g}}$

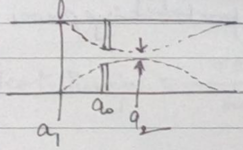
→ Venturimeter



$$\boxed{V_2 = \frac{a_1\sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}}$$

$$\boxed{Q = \frac{C_d\, a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}}$$

orificemeter



$$\boxed{V_2 = \frac{\sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}}$$

$$\boxed{Q = \frac{C_d\, a_0 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}}}$$

coeff of velocity $= \frac{V_{actual}}{V_{ideal}}$

$\boxed{C_c = \text{coeff. of contraction} = \frac{a_2}{a_0}}$

→ Design

Fluctuating loads

stress concentration – $\boxed{K_t = \frac{\sigma_{max}}{\sigma_0} = \frac{S_{ut}/f_{os}}{P/A}}$

Endurance limit = max. ~~no of~~ stress a specimen can bear without failure for ∞ no. of cycles

Notch sensitivity – $\boxed{K_f = \frac{\text{E.L of notched specimen}}{\text{EL of notch free specimen}}}$

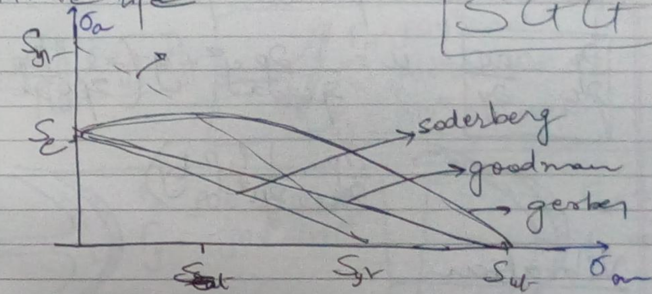
$$\boxed{K_f = 1 + q(K_t - 1)}$$

$S_e = K_a\, K_b\, K_c\, K_d\, S_e'$

K_a → surface finish; K_b → size; K_c → reliability; K_d → $\frac{1}{K_f}$; S_e' → endurance limit of notch free specimen

Finite life

SGG



Goodman $\quad \boxed{\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} = 1}$

Gerber $\quad \boxed{\left(\frac{S_m}{S_{ut}}\right)^2 + \frac{S_a}{S_e} = 1}$

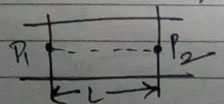
→ Viscous Flow

~~Stress~~ Flow through circular pipe –

$$\boxed{\tau = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{r}{2}\right)} \qquad \boxed{u = -\frac{1}{4\mu}\frac{\partial p}{\partial x}\left[R^2 - r^2\right]}$$

$$\boxed{\bar{u} = \frac{R^2}{8\mu}\left(\frac{-\partial p}{\partial x}\right)} \qquad \boxed{\frac{u_{max}}{\bar{u}} = 2}$$

Pressure drop for given length



$$\boxed{P_1 - P_2 = \Delta p = \frac{32\mu \bar{u} L}{D^2}}$$

$$\boxed{\text{loss of pr. head} = \frac{P_1 - P_2}{\rho g} = \frac{32\mu \bar{u} L}{\rho g D^2}}$$

Flow Between 2 parallel plates

$$\boxed{\frac{\partial p}{\partial x} = \frac{\partial \tau}{\partial y}} \qquad u = \frac{1}{2\mu}\frac{\partial p}{\partial x}y^2 + y\left(-\frac{1}{2\mu}\frac{\partial p}{\partial x}t\right)$$

$$= \frac{\partial p}{\partial x}\cdot\frac{1}{2\mu}(y^2 - ty)$$

→ Vibration

speed = frequency × wavelength

frequency × time period = 2π

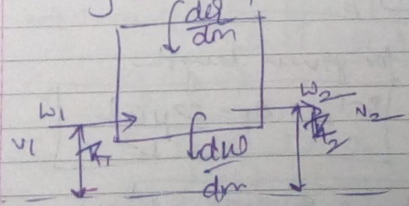
→ Dimensionless Numbers

$$\boxed{P_r = \frac{\mu C_p}{K}} \quad \boxed{R_e = \frac{\rho v L}{\mu}} \quad \boxed{Nu = \frac{hL}{K}} \quad \boxed{\text{Froude } F_r = \frac{v}{\sqrt{lg}}}$$

$$\boxed{St = \frac{Nu}{Re\,Pr}} \quad \boxed{Gr = \frac{L^3 g\beta\Delta T}{\nu^2}}$$

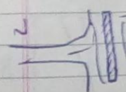
→ SFEE

steady, incompressible, inviscid



$$\boxed{h_1 + \frac{v_1^2}{2} + z_1 g + \frac{dQ}{dm} = h_2 + \frac{v_2^2}{2} + z_2 g + \frac{dW}{dm}}$$

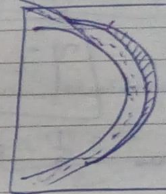
→ Jet Propulsion



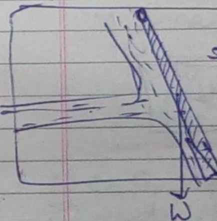
$$\boxed{F = \rho a v^2}$$

$$F_n = \rho a v^2 \sin\theta$$
$$F_x = \rho a v^2 \sin^2\theta$$
$$F_y = \rho a v^2 \cos\theta \sin\theta$$

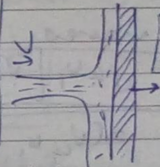
$$F_x = \rho a v^2(1+\cos\theta)$$
$$F_y = -\rho a v^2 \sin\theta$$



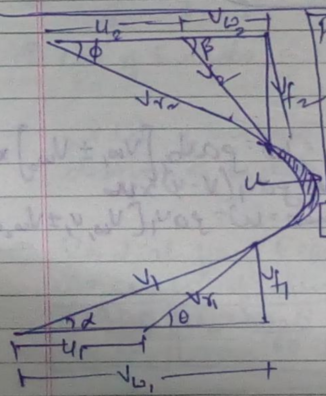
$$F_x = 2\rho a v^2 \cos\theta$$
$$F_y = 0$$



$$\sin\theta = \frac{\rho a v^2}{W}$$



$$\boxed{F = \rho a(v-u)^2}$$



$$F_x = \rho a V_{r_1}[V_{w_1} + V_{w_2}]$$
$$= \rho a V_{r_1}[V_{w_1}]$$
$$\rho a V_{r_1}[V_{w_1} - V_{w_2}]$$

$$\boxed{\text{work done} = F_x \times u}$$

water enters and leaves without shock

$$\Rightarrow V_{r_1} = V_{r_2}$$

radial input $\cancel{\alpha}$ π/2, radial o/p = β = π/2

Series of vanes

→ straight vanes

$$\boxed{W = \rho a V [V-u] \times u}$$

$$\boxed{\eta = \frac{2u(V-u)}{V^2}}$$

$\eta_{max} = \frac{1}{2}$ at $u = \frac{V}{2}$

→ curved vanes

$$\boxed{W = \rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2]}$$

$$\boxed{\eta = \frac{2(V_{w_1} u_1 \pm V_{w_2} u_2)}{V_1^2}}$$

work done

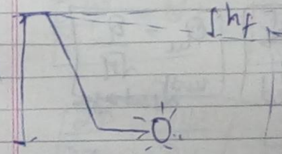
single curved vane = $W = \rho a V_{r_1} [V_{w_1} \pm V_{w_2}] \times u$

series of vanes = $W = \rho a V_1 (V-u) \times u$

series of curved vanes = $W = \rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2]$

→ Pelton wheel

Net head = $H - h_f$



$$\boxed{h_f = \frac{4fLV^2}{2gD}}$$

work done = work done for simple curved vane

KE of jet per second = $\frac{(\rho a V_1) V_1^2}{2}$

η_h = same as curved vanes

$$\boxed{\eta_{h_{max}} = \frac{1+\cos\phi}{2}}$$

① $V = C_v \sqrt{2gH}$ ② $u = \phi \sqrt{2gH} = \frac{\pi D N}{60}$

③ angle of defl^n = 165°

④ No. of buckets = $15 + \frac{D}{2d}$

width of buckets = $5d$

depth of buckets = $1.2d$

→ Radial flow Reaction Turbines

W = series of curved vanes

$\boxed{u_1 = \frac{\pi D_1 N}{60}}$ $\boxed{u_2 = \frac{\pi D_2 N}{60}}$ $\boxed{\eta_h = \frac{V_{w_1} u_1 \pm V_{w_2} u_2}{gH}}$ $\boxed{\text{radial discharge } V_{w_2} = 0}$

Discharge (Q) = $\pi D B V_f$

vel. of flow at inlet

dia of runner at inlet

width of runner at inlet

Francis turbine - inward radial flow reaction turbine

#4

→ **Specific Quantities**

$$\boxed{N_s = \frac{N\sqrt{P}}{H^{5/4}}}$$

$$\boxed{N_u = \frac{N}{\sqrt{H}}}$$ unit speed

$$\boxed{Q_u = \frac{Q}{\sqrt{H}}}$$ unit discharge

$$\boxed{P_u = \frac{P}{H^{3/2}}}$$ unit power

→ **Kinematics**

⇒ continuity eqn $\boxed{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0}$

⇒ ~~continuity eqn~~ acceleration

$$a_x = \frac{du}{dt} = \underbrace{\frac{\partial u}{\partial x}\cdot\frac{dx}{dt} + \frac{\partial u}{\partial y}\cdot\frac{dy}{dt} + \frac{\partial u}{\partial z}\frac{dz}{dt}}_{\text{convective acc}^n} + \underbrace{\frac{\partial u}{\partial t}}_{\text{local acc}^n}$$

Velocity potential fn (ϕ)

$$\boxed{u = -\frac{\partial \phi}{\partial x}} \quad \boxed{v = -\frac{\partial \phi}{\partial y}} \quad \boxed{w = -\frac{\partial \phi}{\partial z}}$$

$$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = 0$$

Streamline & equipotential flow are identical.

Stream Function

$$\boxed{\frac{\partial \psi}{\partial x} = v} \quad \boxed{\frac{\partial \psi}{\partial y} = -u}$$

$$\boxed{\frac{\partial \phi}{\partial x} = \frac{\partial \psi}{\partial y}} \quad \boxed{\frac{\partial \phi}{\partial y} = -\frac{\partial \psi}{\partial x}}$$

Rotational components

$$\boxed{\omega_x = \frac{1}{2}\left[\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right]} \quad \boxed{\omega_y = \frac{1}{2}\left[\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right]}$$

$$\omega_z = \frac{1}{2}\left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]$$

ω_x =	x	y	z
ω_y =	y	z	x
ω_z =	z	x	y

ω_x =	x	y	z
ω_z =	z	x	y
ω_y =	y	x	x

→ **Jacobians**

$$J\left(\frac{u,v}{x,y}\right) = \frac{\partial(u,v)}{\partial(x,y)} = \begin{vmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{vmatrix}$$

⇒ $J = \frac{\partial(u,v)}{\partial(x,y)}$, $J^* = \frac{\partial(x,y)}{\partial(u,v)}$ then $JJ^* = 1$

⇒ $J\left(\frac{u,v}{x,y}\right) = \boxed{J\left(\frac{u,v}{r,s}\right) J\left(\frac{r,s}{x,y}\right)}$

→ **Wronskians**

$$W(y_1, y_2) = \begin{vmatrix} y_1 & y_2 \\ y_1' & y_2' \end{vmatrix}$$

y_1, y_2 are linearly independent if $W \neq 0$

→ Fourier

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx$$

$$\boxed{a_0 = \frac{1}{\pi}\int_{\alpha}^{\alpha+2\pi} f(x)\,dx} \quad \boxed{a_n = \frac{1}{\pi}\int_{\alpha}^{\alpha+2\pi} f(x)\cos nx\,dx}$$

$$\boxed{b_n = \frac{1}{\pi}\int_{\alpha}^{\alpha+2\pi} f(x)\sin nx\,dx}$$

→ Numerical Methods

RK2

input x_0, y_0, x_g, h

$n = \frac{x_g - x_0}{h}$

n-steps

$K_1 = h^* f(x_0, y_0)$

$K_2 = h^* f(x_0+h, y_0+K_1)$

$K = \frac{K_1 + K_2}{2}$

$y_g = y_0 + K$

$x_0 = x_0 + h$

$y_0 = y_g$

RK4

input x_0, y_0, x_g, h

$n = \frac{x_g - x_0}{h}$

n-steps.

$K_1 = h^* f(x_0, y_0)$

$K_2 = h^* f(x_0 + \frac{h}{2}, y_0 + \frac{K_1}{2})$

$K_3 = h^* f(x_0 + \frac{h}{2}, y_0 + \frac{K_2}{2})$

$K_4 = h^* f(x_0 + h, y_0 + K_3)$

$K = \frac{K_1 + 2K_2 + 2K_3 + K_4}{6}$

$y_0 = y_g + K$

$x_0 = x_0 + h$

$y_0 = y_g$

Governor

Euler

$y = f(x, y)$

x_0, x_g, y_0, h

$n = \frac{x_g - x_0}{h}$

n-steps

$y_g = y_0 + h^* f(x_0, y_0)$

$x_0 = x_0 + h$

$y_0 = y_g$

Improved Euler - ~~cauchy~~

Euler Modified

$y = f(x, y)$

x_0, x_g, y_0, accuracy

$n = 2$

$h = \frac{x_g - x_0}{2}$

2-steps

$y_1 = y_0 + h^* f(x_0, y_0)$

$y_{11} = y_0 + \frac{h}{2}^* \left[f(x_0, y_0) + f(x_0+h, y_1) \right]$

if $|y_{11} - y_1| <$ accuracy

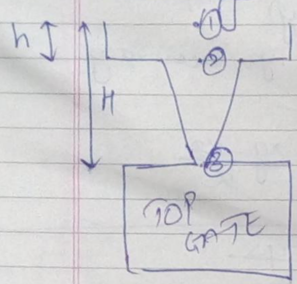
$y_1 = y_{11}$

$y_{11} = y_0 + \frac{h}{2}\left[f(x_0, y_0) + f(x_0+h, y_1) \right]$

$x_0 = x_0 + h$

$y_0 = y_{11}$

→ Moulding



Time taken to fill mould

→ top gate $t = \frac{V_{mould}}{A_3\sqrt{2gH}}$

→ bottom gate $t = \sqrt{\frac{2}{g}}\,\frac{A_m}{A_g}\left[\sqrt{H} - \sqrt{H-h}\right]$

Sprue $\frac{A_3}{A_2} = \sqrt{\frac{h}{H}}$

Design of Risers

t = solidification time $= K\left(\frac{V}{SA}\right)^2$

Freezing Ratio $= \frac{(SA/V)_{casting}}{(SA/V)_{riser}}$ → must be >1.

Caine's relationship $x = \frac{0.1}{y-0.03} + 1$ → for steel

Top Riser $(V/A) = d/6$ → same for side riser

→ Rolling

max. red^n in thk $= \mu^2 R = \Delta h_{max}$

roll contact length $= \sqrt{R\Delta h}$

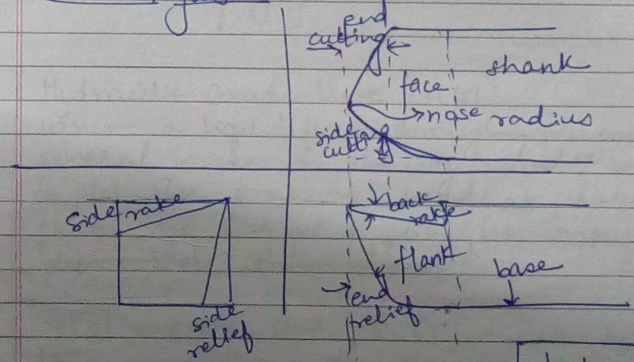
contact angle / angle of bite $\tan\alpha = \sqrt{\frac{\Delta h}{R}}$

Roll force

$P_{av} = 2K\left(1 + \frac{\mu L}{2h_{av}}\right)$

$K = \frac{\sigma_y}{\sqrt{3}}$ $\quad h_{av} = \frac{h_i + h_f}{2}$

→ Tool Angles



For orthogonal cutting

$\frac{\tan(\text{back rake})}{\tan(\text{side rake})} = \tan(\text{side cutting})$

back rake	α_b
side rake	α_s
end relief	γ_e
side relief	γ_s
end cutting	ψ_e
side cutting	ψ_s

SDOF

→ Coulomb Damping

left to right $\boxed{m\ddot{x} + Kx + \mu N = 0}$
right to left $\boxed{m\ddot{x} + Kx - \mu N = 0}$

soln

L-R $\boxed{x(t) = A_1 \cos\omega t + A_2 \sin\omega t - \frac{\mu N}{K}}$

R-L $\boxed{x(t) = A_3 \cos\omega t + A_4 \sin\omega t + \frac{\mu N}{K}}$

loss of amplitude in every cycle

$\boxed{X_n = X_{n-1} - \frac{4\mu N}{K}}$

→ Forced Vibration

$F(t) = F_0 \cos(\omega t)$

$\omega \neq \omega_n$ (A) $x(t) = x_h(t) + x_p(t)$

$x_h(t)$ = solⁿ of homogeneous eqn
$A\cos(\omega t) + B\sin(\omega t)$

$x_p(t) = C\cos(\omega t)$

$C = \frac{F_0}{K - m\omega^2} = \frac{F_0/K}{(1-r^2)}$

r - frequency ratio $= \frac{\omega}{\omega_n}$

$x(t) = A\cos\omega_n t + B\sin\omega_n t + \frac{F_0/K}{(1-r^2)}\cos\omega t$

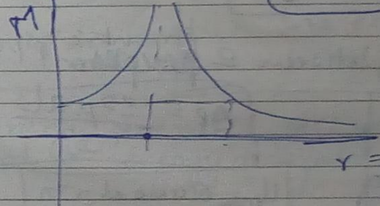
$\omega = \omega_n$ (B) $x_p(t) = Dt\sin\omega t$

$D = \frac{F_0}{2m\omega_n}$

$\boxed{x(t) = A\cos\omega_n t + B\sin\omega_n t + \frac{F_0 t\sin\omega t}{2m\omega_n}}$

M = magnification factor $= \frac{1}{|1-r^2|}$

$= \frac{X_{dynamic}}{X_{static}} = \frac{\frac{F_0/K}{(1-r^2)}}{F_0/K}$



$r = \frac{\omega}{\omega_n}$

~~Harmonically Forced Viscous damped~~

~~$m\ddot{x} + c\dot{x} + Kx = F(t)$~~

~~$x = X\cos(\omega t - \phi)$~~

$x(t) = \left(x_0 - \frac{F_0}{K - m\omega^2}\right)\cos\omega_n t + \left(\frac{\dot{x}_0}{\omega_n}\right)\sin\omega_n t + \frac{F_0}{K - m\omega^2}\cos\omega t$

$x(t) = x_0\cos\omega_n t + \frac{\dot{x}_0\sin\omega_n t}{\omega_n} + \frac{F_0}{K}\left(\frac{\omega_n t}{2}\right)\sin\omega_n t$

Harmonically Forced Viscous Damped vibration

$\boxed{m\ddot{x} + c\dot{x} + Kx = F(t)}$

let $x = X\cos(\omega t - \phi)$ → find $\dot{x}$ & $\ddot{x}$ & substitute in EOM.

compare sines & cosines

$\phi = \tan^{-1}\left(\frac{2\zeta\omega_n\omega}{\omega_n^2 - \omega^2}\right) = \left(\frac{2\zeta r}{1-r^2}\right)$

→ Buckling $\boxed{P_e = \frac{\pi^2 EI}{l_e^2}}$ $\boxed{\frac{d^2y}{dx^2} + \frac{P_y}{EI} = 0}$

i) Both ends hinged $\boxed{l = l_e}$
ii) one fixed, other free $\boxed{l_e = 2l}$
iii) one fixed, other pin jointed $= \boxed{l_e = \frac{l}{\sqrt{2}}}$

iv) Both fixed $\boxed{l_e = \frac{l}{2}}$

Rankine load $\boxed{\frac{1}{P_{rankine}} = \frac{1}{P_{crush}} + \frac{1}{P_{Euler}}}$

→ Spur Gear

$\boxed{\text{pitch} = \frac{\pi d'}{z}}$ → PCD, → no. of teeth

diametral pitch $\boxed{P = \frac{z}{d'}}$

module $\boxed{\frac{d'}{z} = m}$

$\boxed{\begin{array}{c}\text{Gear ratio} \\ i = \sqrt{i'}\end{array}}$ $\boxed{i' = \frac{\text{no. of teeth in 1st gear}}{\text{no. of teeth in LAST gear of final stage}}}$

$\boxed{\text{contact ratio} = \frac{\text{length of arc of contact}}{\pi m}}$

$G = \frac{T}{t}$

1

$\boxed{\text{center distance} = \frac{m(z_p + z_g)}{2}}$

→ Compressor

→ $\boxed{W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]}$

$\boxed{\text{intercooler pressure} = \sqrt{P_1 P_3}}$

P_1 ↓ c1
P_2 ← intercooler
P_3 ↓ c2

→ $\boxed{dU = mC_v \Delta T}$ $\boxed{dH = mC_p \Delta T}$

→ mass of flywheel = $m = 2\pi R \times A \times \rho$

→ $Q = U + PV$

$TdS = U + PdV$ holds good for any process undergone by a closed system.

→ Gas Turbine

On installing a regenerator, specific output remains same though efficiency is improved.

→ Availability

$\boxed{W_{min} = mC_p\left(\frac{T_i^2}{T_f} + T_f - 2T_i\right)}$

→ Laplace Identities

$\boxed{L[e^{at} f(t)] = \bar{f}(s-a)}$ $\boxed{L[t^n f(t)] = (-1)^n \frac{d^n}{ds^n} \bar{f}(s)}$

$\boxed{L[f(at)] = \frac{1}{a} \bar{f}\left(\frac{s}{a}\right)}$ $\boxed{L\left[\frac{f(t)}{t}\right] = \int_s^\infty \bar{f}(s)\,ds}$

$\boxed{L\left[\int_0^t f(u)\,du\right] = \frac{\bar{f}(s)}{s}}$ $\boxed{L[f^n(t)] = s^n \bar{f}(s) - s^{n-1} f(0) - s^{n-2} f'(0) \ldots - f^{n-1}(0)}$

→ Boundary layer

Boundary layer thickness = 0.99U

Displacement thk − $\boxed{\delta^* = \int_0^\delta \left(1 - \frac{u}{U}\right) dy}$

Momentum thickness $\boxed{\theta = \int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy}$

Energy thickness $\boxed{\delta_e = \int_0^\delta \frac{u}{U}\left(1 - \frac{u^2}{U^2}\right) dy}$

→ Slenderness Ratio = $\frac{\text{min unsupported length of column}}{\text{min radius of gyration of c-s area}}$

Buckling factor = $\frac{\text{equivalent length}}{\text{min radius of gyration}}$

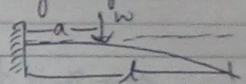
short (8d) med. (30d) long

→ Mobility of A Mechanism

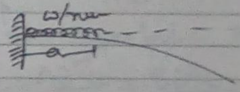
- It is the no of axes an object can rotate/translate in a 3D space.

$\boxed{M = EI \frac{d^2y}{dx^2}}$

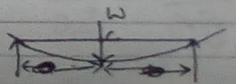
→ Defl^n of Beams—

i) 

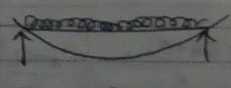
$\boxed{y_{max} = -\frac{Wa^2}{6EI}(3L-a)}$

ii) 

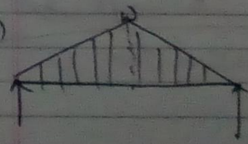
$y_{max} = -\left[\frac{Wa^3}{8EI} + \frac{Wa^2}{6EI}(l-a)\right]$

iii) 

$\boxed{y_c = \ldots}$ $\boxed{-\frac{Wl^3}{48EI}}$

iv) 

$\boxed{y_{max} = \frac{5Wl^3}{384EI}}$

v) 

$\boxed{y_{max} = \frac{Wl^4}{120EI}}$

→ $y = A + Bx + Cx^2$

$$\boxed{\begin{aligned} \Sigma y &= nA + B\Sigma x + C\Sigma x^2 \\ \Sigma xy &= A\Sigma x + B\Sigma x^2 + C\Sigma x^3 \\ \Sigma x^2 y &= A\Sigma x^2 + B\Sigma x^3 + C\Sigma x^4 \end{aligned}}$$

→ Multiple regression
$y = a + bx_1 + cx_2$

$$\boxed{\begin{aligned} \Sigma y &= nA + B\Sigma x_1 + C\Sigma x_2 \\ \Sigma x_1 y &= A\Sigma x_1 + B x_1^2 + C\Sigma x_1 x_2 \\ \Sigma x_2 y &= A\Sigma x_2 + B\Sigma x_1 x_2 + C x_2^2 \end{aligned}}$$

→ Newton Raphson
given $y = f(x)$ - solve it
initial guess x_0.

x_A	x_B	$\lvert x_A - x_B \rvert$
x_0	x_1	
x_1	x_2	
x_2	x_3	
⋮		

$$x_B = x_A - \frac{f(x_A)}{f'(x_A)}$$

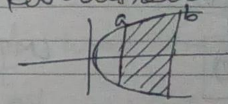
→ 2-D stress system

$$\boxed{\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}}$$

$$\boxed{\sigma_{1\&2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}}$$

→ Volume of Revolution

$y = \sqrt{x}$



$V = \int \pi r^2 dx \qquad r = y \qquad = \pi \int_a^b y^2 dx$

$$\boxed{= \pi \int_a^b x\, dx}$$

→ Grashof's criteria -
4-bar link will contain a rotating pair if sum of shortest & longest link is greater than sum of other two.

→ Mobility of a statically indeterminate system is ≤ -1.

→ Vorticity Vector $= \nabla \times \vec{V}$

→ ~~Sto~~ Hyperbolic PDE

$$A\frac{\partial^2 u}{\partial x^2} + B\frac{\partial^2 u}{\partial x \partial y} + C\frac{\partial^2 u}{\partial y^2} + F\left[x, y, u, \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}\right] = 0$$

→ MOI of circle $= \boxed{\frac{\pi d^4}{64}}$

J for solid shaft $= \boxed{\frac{\pi}{32}(D^4)}$

J for hollow shaft $= \boxed{\frac{\pi}{32}(D_1^4 - D_2^4)}$

→ Heat Exchanges

$$\boxed{Q = UA(LMTD)}$$

$$LMTD = \frac{\theta_2 - \theta_1}{\ln\left(\frac{\theta_2}{\theta_1}\right)}$$

$$NTU = \frac{UA}{C_{min}}$$

$$\boxed{C_{max/min} = \dot{m} \times sp.heat}$$

→ Diesel Engine

$$\eta = 1 - \frac{\text{Heat rejected}}{\text{Heat added}} = \boxed{1 - \frac{C_v(\Delta T)}{C_p(\Delta T)}}$$

→ Clausius-Clapeyron

$$\boxed{\frac{dP}{dT} = \frac{L}{T\Delta v} = \frac{h_{fg}}{T v_{fg}} = \frac{s_g - s_f}{v_g - v_f}}$$

→ Pitot Tube

$$\boxed{V = \sqrt{\frac{2\Delta p}{\rho}} = \sqrt{\frac{2(\rho_w - \rho)gh}{\rho}}}$$

→ If $\vec{F}$ is irrotational, ϕ exists such that $\vec{F} = \text{grad}\,\phi$ where ϕ is called scalar potential fn.

$$\text{grad}\,\phi = \frac{\partial f}{\partial x}\hat{i} + \frac{\partial f}{\partial y}\hat{j} + \frac{\partial f}{\partial z}\hat{k}$$

→ For cylinder $\sigma_1, \sigma_2, \sigma_3$

$$\sigma_1 = \frac{pd}{2t} \text{ - hoop stress}$$

$$\sigma_2 = \frac{pd}{4t} = \text{longitudinal stress}$$

→ Soderberg relation

σ_1 = given σ_2 = given

$$\boxed{\sigma_y = 0.55\,\sigma_u} \qquad \boxed{\sigma_e = 0.50\,\sigma_u}$$

$$\boxed{\sigma_m = \frac{\sigma_1 + \sigma_2}{2}} \text{ mean} \qquad \boxed{\sigma_v = \frac{\sigma_1 - \sigma_2}{2}} \text{ variable}$$

$$\boxed{\frac{\sigma_m}{\sigma_y} + \frac{\sigma_v}{\sigma_e} = \frac{1}{fos}}$$

→ Fins

① Infinitely long

$$\boxed{\frac{t - t_a}{t_0 - t_a} = e^{-mx}} \qquad \boxed{Q_{fin} = \sqrt{hPKA}\,(t_0 - t_a)}$$

②

$$\boxed{\frac{t - t_a}{t_0 - t_a} = \frac{\cosh m(L-x)}{\cosh(mL)}} \qquad \boxed{Q = \sqrt{hPKA}\,(t_0 - t_a)\tanh(mL)}$$

③

$$\boxed{\frac{t - t_a}{t_0 - t_a} = \frac{\cosh m(L-x) + \frac{h}{km}\sinh m(L-x)}{\cosh(mL) + \frac{h}{km}\sinh(mL)}}$$

$$\boxed{Q_{fin} = \sqrt{hPKA}\,(t_0 - t_a)\left[\frac{\tanh(mL) + \frac{h}{km}}{1 + \frac{h}{km}\tanh(mL)}\right]}$$

Numerical Methods

① Trapezoidal

$$\int f(x) = \frac{h}{2}\left[y_0+y_n+2(y_1+y_2+\cdots+y_{n-1})\right]$$

② simpsons $1/3^{rd}$ (n=even)

$$\int f(x) = \frac{h}{3}\left[y_0+y_n+4(y_1+y_3+\cdots)+2(y_2+y_4+y_6+\cdots)\right]$$

③ simpsons $\frac{3}{8}^{th}$

$$\int f(x) = \frac{3h}{8}\left[y_0+y_n+3(y_1+y_2+\cdots)+2(y_3+y_6+\cdots)\right]$$

④ Eigen Values

$\Rightarrow A \rightarrow |A-\lambda I| \rightarrow |A-\lambda I|=0$ solve for λ.

These are eigen values.

$\Rightarrow$ Take λ one by one $\rightarrow$ put it into $(A-\lambda I)\begin{bmatrix}x\\y\end{bmatrix}=0$

convert to $\boxed{\frac{x}{a}=\frac{y}{b}}$ (a,b) ~~are~~ is eigen vectors.

$\Rightarrow$ Eigen values of Δ^r matrix is just the diagonal elements.

$\Rightarrow$ Cayley hamilton - every matrix satisfies its own characteristic eqn.

→ Hooke's law holds good upto proportional limit

→ Coefficient of Restitution

$e=0.9 \Rightarrow \boxed{V_{after\ impact} = 0.9\ velocity\ before\ impact}$

but $\boxed{h_{after\ impact} \neq 0.9\, h_{before\ impact}}$

→ $x = f(t)$

$\boxed{\frac{dx}{dt} = \text{instantaneous velocity}}$

$\boxed{\frac{d^2x}{dt^2} = \text{— " — acc}^n}$

average $acc^n = \frac{v(x_f)-v(x_i)}{t_f - t_i}$

→ Velocity is tangent to streamline flow.

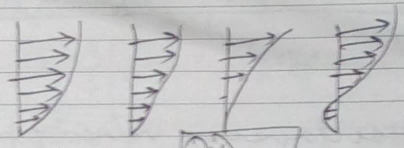
→ laminar flow b/w 2 concentric pipes

$\boxed{\tau = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{r}{2}\right)}$

$\boxed{u = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{R^2-r^2}{4\mu}\right)}$

$\boxed{\bar{u} = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{R^2}{8\mu}\right)}$

→ In a 2-D free stream flow, the separation point where fluid leaves the body in contact will be that point where the ~~fluid~~ fluid profile ~~tangent~~ has zero slope on wall.



$$\boxed{\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0}$$

→ MK ① TGA Q 35

→ $\nabla \times \vec{V} = 0 \Rightarrow$ irrotational

→ Buckling

⇒ both hinged $l_e = l$

⇒ one fixed other free $l_e = 2l$

⇒ one fixed other hinged $l_e = l/\sqrt{2}$

⇒ both fixed $= l_e = l/2$

→ Boundary layer thickness $= \boxed{\frac{5x}{\sqrt{Re_x}} = \delta}$

→ Q MK ① TGA Q 46

$$\boxed{\epsilon_x = \frac{1}{E}(\sigma_x - \mu\sigma_y)} \quad \boxed{\epsilon_y = \frac{1}{E}(\sigma_y - \mu\sigma_z)}$$

$$\gamma_{xy} = \frac{\tau_{xy}}{G}$$

$$\boxed{\epsilon_{1,2} = \frac{\epsilon_x+\epsilon_y}{2} \pm \sqrt{\left(\frac{\epsilon_x-\epsilon_y}{2}\right)^2 + \gamma_{xy}^2}}$$

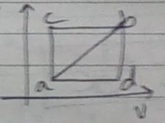
→ Thermal Engineering

① $Q = mC_v\Delta T$

$\boxed{dQ = mC_v\,dt}$ if $C_v = f(t)$

$dQ = mC_v\,dt = \boxed{m\int f(t)\,dt}$

② Quasi-static process - locus of equlb point only

③ 

$$\underbrace{Q_{acb}}_{\text{path fn}} = \underbrace{U_b - U_a}_{\text{depends only on final \& initial pts}} + \underbrace{W_{acb}}_{\text{path fn}}$$

④ Gas constant $\boxed{R = 287\,J/kgK}$

⑤ $W < 0 \Rightarrow$ work is done on the system.

⑥ Kelvin-Plank - impossible to construct engine that takes in heat from a reservoir and converts it entirely to work.

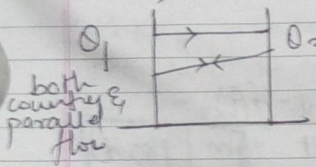
⑦ Unavailable energy $= \Delta S \times Temp_{final}$.

⑧ Thermodynamic Relations

maxwell → T P S V

Joule Thomson $\boxed{\left(\frac{\partial h}{\partial P}\right)_T = -\mu C_p}$ $\boxed{\mu = \left(\frac{\partial T}{\partial P}\right)_h}$

→ LMTD



$$= \boxed{\frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)}}$$

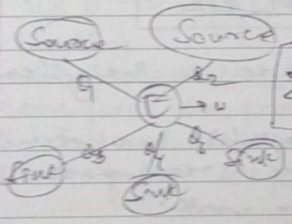
→ Spherical vessels

$$\boxed{\sigma_c = \frac{Pd}{4t}}$$

→ $\boxed{E = 2C\left(1 + \frac{1}{m}\right)}$ $\boxed{\frac{1}{E} = \frac{1}{3C} + \frac{1}{9K}}$

$\boxed{E = 3K\left(1 - \frac{2}{m}\right)}$

→



$\boxed{\sum \frac{Q}{T} = 0}$

$\boxed{Q_1 + Q_2 = W + Q_3 + Q_4 + Q_5}$

→ Partial pressure of a gas = $\frac{n_x V_{px}}{\sum n_i V_{p_i}}$

n = no. of moles

P_v = vapour pressure

→ When talking about compression ratio, we refer to V_2/V_1 & not P_2/P_1

→ Water tube boilers are used for high pressure high output applications.

→ 1st Law is valid for all processes, not just reversible or cyclic.

→ For liquids and solids, $\boxed{C_p = C_v}$.

→ Max. work that can be extracted

$$\boxed{W_{max} = (U_2 - U_1) - T_0(S_1 - S_2) + P_0(V_1 - V_2)}$$

P_0, T_0 are different from state ①, & ②.

$\boxed{U_2 - U_1 = mC_v \Delta T}$

→ $\boxed{\text{Available Energy} = C_p(T_1 - T_0) - T_0 C_p \ln\left(\frac{T_1}{T_2}\right)}$

$= \boxed{\Delta h - T_0 \Delta S}$

→ Fluids

① For a flow to be physically possible,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0.$$

② ϕ - vel. potential

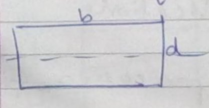
→ if it exists, flow should be irrotational

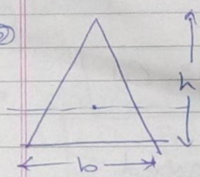
→ if ϕ satisfies laplace eqn, it is irrotational flow

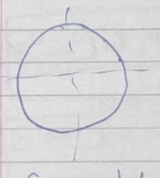
irrotational flow

$\boxed{\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0}$ $\boxed{\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0}$

→ Moment of Inertia

① 
$\frac{bd^3}{12}$

② 
$\frac{bh^3}{36}$

③ 
$\frac{\pi d^4}{64}$

→ Gruebler's criteria

$F = 3(N-1) - 2P_1 - P_2 - 6P_6 - 5P_5 - 4P_4 - 3P_3$

P_i = no. of pairs with i-DOF
N = no. of links

also, all the idle pairs are subtracted.

→ Bezier Curve defined using N- discrete points passes through 2 points.

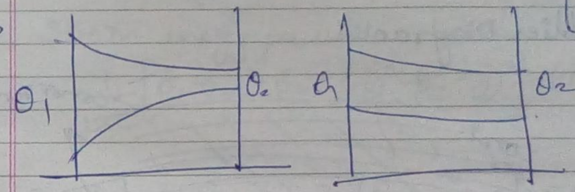
→ Pressure $P = \frac{2}{3} E \rightarrow$ mean KE of gas

→ $\boxed{\text{Availability} = \Delta Q - T\Delta S = \Delta Q - T\left[\Sigma \frac{Q_i}{T_i}\right]}$

→ Sommerfield No. = $\left(\frac{\mu N}{p}\right)\left(\frac{r}{c}\right)^2$

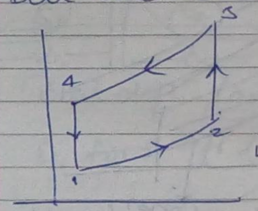
bearing modulus
rpm
journal bearing
Bearing characteristic number
safe load
clearance

$\boxed{p = \frac{W}{ld}}$

→ 

→ Pelton wheel ⇒ for max η → $\frac{\text{jet vel}}{2}$ = vel. of wheel

→ Bell-colemann



$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}}$ → DON'T put γ unless stated

$W_{2-3} = C_p \Delta T$
$W_{4-1} \Rightarrow C_p \Delta T$

net work $= W_{4-1} - W_{2-3}$

net refrigerating effect $C_p(\Delta T)$

($T_{\text{air just coming out of expansion}} - T_{\text{room temp}}$)

→ Differential Eqn

$M\,dy + N\,dx = 0$

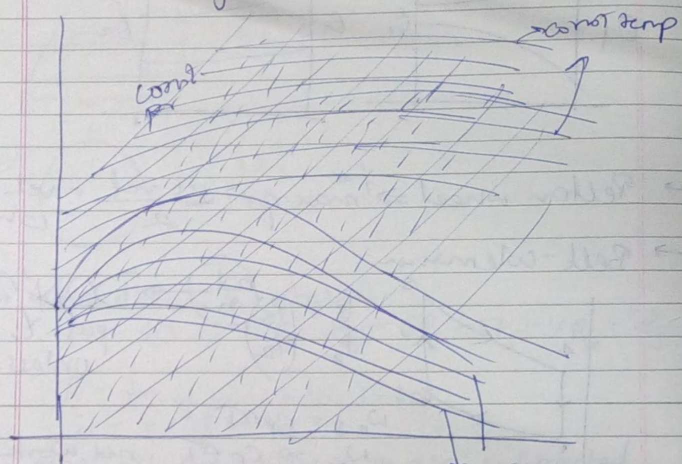
for exact DE → $\boxed{\frac{\partial M}{\partial x} = \frac{\partial N}{\partial y}}$

→ 1 stoke $= 1\,\frac{cm^2}{s}\ (\nu)$

1 poise $= \frac{N s}{m^2}\ (\mu)$

$$\boxed{\nu = \frac{\mu}{\rho}}$$

→ Mollier Diagram



→ Working principle of thermometer is best explained by zeroth law

→ Heating

$\alpha \Delta T = \text{strain} = \frac{\Delta L}{L}$

$$\boxed{\alpha \Delta T \neq \Delta L}$$

→ Shells

$$\boxed{\sigma_1 = \sigma_t = \frac{pd}{2t}}$$
$= \sigma_c$ hoop

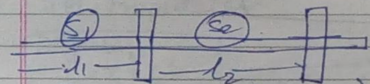
$$\boxed{\sigma_2 = \sigma_\ell = \frac{pd}{4t}}$$

→ Strain energy per unit volume

$= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]$ (TGA)

$= \frac{1}{2E}\left[\sigma_1^2+\sigma_2^2+\sigma_3^2 - 2\mu(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)\right]$ (RK Raj)

→ Shafts in Series



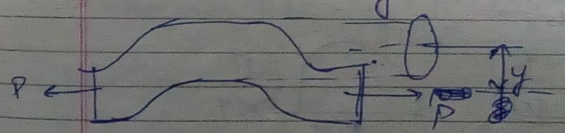
Total defl^n (angle) —

θ_1 for shaft l_1 + θ_2 for shaft l_2 and not (l_1+l_2)

→ For shafts in torsion, θ is in radians.

$$\boxed{\frac{\tau}{R} = \frac{C\theta}{L} = \frac{T}{I_P}}$$

→ Eccentric loading



$\sigma = \frac{P}{A} + \frac{My}{I}$ $\boxed{M = Py}$

$$e_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E} - \frac{\mu\sigma_3}{E}$$

$$e_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_3}{E}$$

$$e_3 = \text{---}$$

$$\sigma_1 = \frac{E}{1-\mu^2}(e_1 + \mu e_2)$$

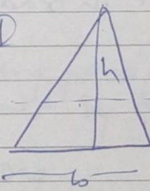
$$\sigma_2 = \frac{E}{1-\mu^2}(e_2 + \mu e_1)$$

$$\tau_{xy} = \frac{E\mu}{2(1+\mu)}$$

→ 2D stress system

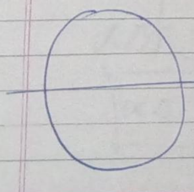
$$\begin{bmatrix} \tau & + & - \\ - & 0 & -\tau \end{bmatrix}\begin{bmatrix} S2 \\ 0 \\ C2 \end{bmatrix} = \begin{bmatrix} \sigma_n \\ \tau \end{bmatrix}$$ and also $\boxed{\sigma_r = \sqrt{\sigma_n^2 + \tau^2}}$

→ MOI



$bh^3/36$

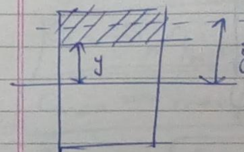
$bh^3/12$



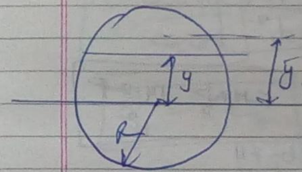
$$\frac{\pi d^4}{64}$$

$$\frac{\pi d^4}{2 \times 64}$$

→ Shear Stresses



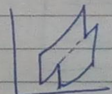
$$\boxed{\tau = \frac{6S}{bd^3}\left(\frac{d^2}{4} - y^2\right)}$$ $$\boxed{\tau_{max} = \frac{3}{2}\cdot\frac{S}{bd}}$$



$$\boxed{\tau = \left(\frac{4}{3}\right)\left(\frac{S}{\pi R^4}\right)(R^2 - y^2)}$$

$$\boxed{\tau_{max} = \frac{4}{3}\frac{S}{\pi R^2}}$$

→ Jet Propulsion



Diffuser $T_2 = T_1 + \frac{C_a^2}{2 C_p \eta_d}$

Nozzle exit vel $= \sqrt{2 \times \eta \times C_p (T_5' - T_6)}$

Thrust $T = (C_j - C_a)\frac{N}{\text{g of a.}}$ $\left(1 + \frac{m_f}{m_a}\right)(C_j - C_a)$

Thrust Power $= (C_j - C_a) C_a$ Watt

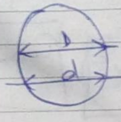
Propulsive power $= \frac{\left(1 + \frac{m_f}{m_a}\right) C_j^2 - C_a^2}{2} = \boxed{\frac{C_j^2 - C_a^2}{2}}$

Propulsive efficiency $= \frac{2}{C_j / C_a + 1} =$

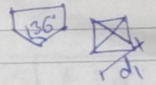
Thermal efficiency $= \frac{\frac{\left(1 + \frac{m_f}{m_a}\right) C_j^2 - C_a^2}{2}}{\left(\frac{m_f}{m_a} \times CV\right)} =$

$\boxed{\text{overall } \eta = \eta_{th} \times \eta_{prop}}$

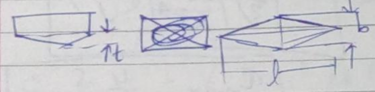
→ Hardness

Brinell 

$$\boxed{BHN = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}}$$

Vickers 

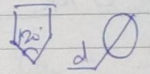
$$\boxed{VHN = \frac{1.72P}{d_1^2}}$$

Knoop 

$$\boxed{KHN = \frac{14.2P}{l^2}}$$

l/b = 7/1

b/t

Rockwell 

→ Composites

$x_1\%$ of E_1 & $x_2\%$ of E_2

$$\boxed{E_{net} = \frac{x_1}{100} \times E_1 + \frac{x_2}{100} \times E_2}$$

→ $\boxed{\text{Hydraulic Radius} = \frac{4\,\text{Area}}{\text{Perimeter}}}$

→ Heat Exchangers

$$\boxed{\varepsilon = \frac{Q_{actual}}{Q_{maximum}}}$$

$$\boxed{C_h = \dot{m}_h C_{p_h}} \qquad \boxed{C_c = \dot{m}_c C_{p_c}}$$

$$\boxed{C_{max} = \max(C_h, C_c)} \qquad \boxed{C_{min} = \min(C_h, C_c)}$$

$$\boxed{R = \frac{C_{min}}{C_{max}}} \qquad \boxed{NTU = \frac{UA}{C_{min}}}$$

$$\boxed{Q = \varepsilon C_{min}(t_{h_1} - t_{c_1})}$$

$$\varepsilon = \boxed{\frac{C_c(t_{c_2} - t_{c_1})}{C_{min}(t_{h_1} - t_{c_1})}} = \boxed{\frac{C_h(t_{h_1} - t_{h_2})}{C_{min}(t_{h_1} - t_{c_1})}}$$

$$\boxed{\text{Parallel } \varepsilon = \frac{1 + e^{-NTU(1+R)}}{1+R}}$$

$$\boxed{\text{Counter flow } \varepsilon = \frac{1 - e^{-NTU(1-R)}}{1 - Re^{-NTU(1-R)}}}$$

→ Psychrometry

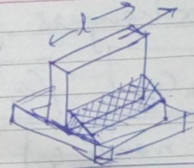
absolute humidity $\omega = \frac{\text{mass of water vapour}}{\text{mass of dry air}} = \boxed{0.622 \frac{P_v}{P_a}} = \boxed{\frac{0.622 P_v}{P_t - P_v}}$

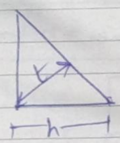
degree of saturation $\mu = \frac{\text{mass of dry vapour in unit mass of dry air}}{\text{mass of vapour associated with saturated unit mass of dry air}}$ $= \boxed{\frac{P_v}{P_{vs}}\left(\frac{P_t - P_{vs}}{P_t - P_v}\right)}$

relative humidity $\boxed{\phi = 1.6\,\omega \frac{P_a}{P_{vs}}}$

Welding

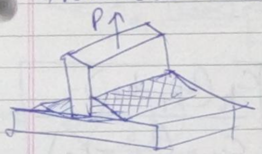
Parallel Fillet Weld





$$\boxed{P = t l \tau = \frac{h}{\sqrt{2}} l \tau}$$

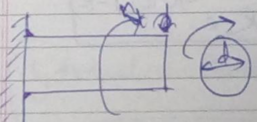
Transverse Fillet Weld



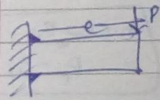
$$\boxed{P = t l \tau = \frac{h}{\sqrt{2}} l \tau}$$

$$P_{max\ parallel} = \frac{h}{\sqrt{2}} l \tau = \boxed{0.707 h l \tau}$$

$$P_{max\ transverse} = \boxed{0.828 h l \tau}$$



$$\boxed{\tau = \frac{M_t}{2\pi t r^2}}$$



$$\tau = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{(P\times e)\times r}{\pi t r^3}\right)^2 + \left(\frac{P}{\pi D t}\right)^2}$$

Whirling of shafts

for whirling,

$$\left(\frac{m\omega^2}{EI}\right)^{1/4} = \frac{\pi}{l}, \frac{2\pi}{l}, \frac{3\pi}{l} \dots$$

$$\Rightarrow \omega^{1/2} = \frac{\pi}{l}\left(\frac{EI}{m}\right)^{1/4}, \frac{2\pi}{l}\left(\frac{EI}{m}\right)^{1/4}, \frac{3\pi}{l}\left(\frac{EI}{m}\right)^{1/4} \dots\dots$$

$$f_n = (2\pi\omega_n) = \frac{\pi}{2}\sqrt{\frac{EI}{ml^4}}, \frac{4\pi}{2}\sqrt{\frac{EI}{ml^4}}, \frac{9\pi}{2}\sqrt{\frac{EI}{ml^4}} \dots$$

or $\boxed{f_n = \frac{n^2\pi}{2}\sqrt{\frac{EI}{ml^4}}}$ → critical speed of shaft for n-nodes.

Critical speeds

lowest critical speed $= \boxed{3.562\sqrt{\frac{gEI}{wl^4}}}$

higher — $\boxed{\frac{\pi}{2}\left(n+\frac{1}{2}\right)^2\sqrt{\frac{gEI}{wl^4}}}$

lowest almost corresponds to n=1.

→ Tangential acc^n = $2N\omega$

Angular acc^n = $\omega^2 r$

Resultant = $\sqrt{a_t^2 + a_a^2}$

→ Linear eqns are of form

$$P_1 \frac{d^n y}{dx^n} + P_2 \frac{d^{n-1} y}{dx^{n-1}} + P_3 \frac{d^{n-2} y}{dx^{n-2}} \dots + P_n = X$$

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→ Available Energy

$$= \Delta h - T_0 \Delta S + \frac{V^2}{2} + gz$$

Δh ↓ $Q\Delta T$; $T_0\Delta S$ ↓ ; $\frac{V^2}{2}$ ↓ KE ; gz ↓ PE

$\boxed{\begin{array}{l} \Delta S \text{ eqn} \\ Q\,R \\ W\,W \\ Q\,R \end{array}}$

→ Load fluctuating from x kN & y kN,

$$\boxed{\sigma_{mean} = \frac{x+y}{2}} \qquad \boxed{\sigma_{amplitude} = \frac{x-y}{2}}$$

→ Electrochemical machining

mass removed per unit time $= \boxed{\frac{m}{t} = \frac{EI}{F \times \rho}}$

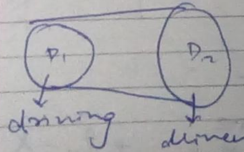
E = electrochemical equivalent = $\frac{\text{atomic weight}}{\text{valency}}$

I = current

F = Faraday's constant = 96500

ρ = density

→ Belt Drive



$$\boxed{\text{Velocity Ratio} = \frac{N_2}{N_1} = \frac{D_1+t}{D_2+t}}$$

peripheral speed of driving pulley $= \omega_1 \left(\frac{D_1+t}{2}\right)$

S_1 = slip b/w belt & driving pulley

S_2 = ——"—— driven pulley

speed of belt on driving pulley $= \omega_1 \left(\frac{D_1+t}{2}\right)\left(\frac{100-S_1}{100}\right)$

this is also the speed of belt on driven pulley

speed of driven pulley $= \boxed{\omega_1 \left(\frac{D_1+t}{2}\right)\left(\frac{100-S_1}{100}\right)\left(\frac{100-S_2}{100}\right)}$

length of belt − open belt $= \boxed{\pi(R+r) + \frac{(R-r)^2}{C} + 2C}$

crossed belt − $\boxed{\pi(R+r) + \frac{(R+r)^2}{C} + 2C}$

Tensions

$\boxed{\frac{T_1}{T_2} = e^{\mu\theta} \quad T_1 = \text{tight side} \quad \text{Flat belt}}$

$\boxed{\frac{T_1}{T_2} = e^{\frac{\mu\theta}{\sin\alpha}} \quad \text{V-belt.}}$

$\boxed{\text{Power transmitted} = (T_1 - T_2)\, V}$

$\boxed{\text{centrifugal tension} = mv^2 = T_c}$ (m ↓ mass per unit length)

$\boxed{\text{max power transmitted when } T_c = \frac{T}{3} \text{ \& } V_{max} = \sqrt{\frac{T}{3m}}}$

→ Vector Calculus

Greens Theorem

$$\boxed{\int_C (\phi\,dx + \psi\,dy) = \iint \left(\frac{\partial \psi}{\partial x} - \frac{\partial \phi}{\partial y}\right) dx\,dy}$$

Stokes Theorem

$$\boxed{\int_C F \cdot dR = \int_S \text{curl}\, F \cdot N\, ds}$$

Gauss Divergence

$$\boxed{\int_S F \cdot N\, ds = \int_E \text{div}\, F\, dv}$$

→ A specimen is loaded in the plastic region and then unloaded.

Ds — linear elastic region is increased
— ductility is reduced
— yeild strength is increased.

→ Transmissibility $= \boxed{\dfrac{\sqrt{1+(2\xi r)^2}}{\sqrt{(1-r^2)^2+(2\xi r)^2}}}$

→ length of a curve between x_1 & x_2

$$\boxed{\int_{x_1}^{x_2} \sqrt{1+\left(\frac{dy}{dx}\right)^2}}$$

→ If a cycle is anticlockwise, work done is positive, else negative.

→ $$\boxed{e_x = \frac{\sigma_x}{E} - \frac{\cancel{\mu}}{mE}(\sigma_y + \sigma_z)}$$

$$\boxed{e_y = \frac{\sigma_y}{E} - \frac{(\sigma_x+\sigma_z)}{mE}} \quad \boxed{e_z = \frac{\sigma_z}{E} - \frac{(\sigma_x+\sigma_y)}{mE}}$$

$$\boxed{\sigma_x = \frac{E\left[(1-m)e_x + m(e_y+e_z)\right]}{(1+m)(1-2m)}}$$

$$\boxed{\sigma_y = \frac{E\left[(1-m)e_y + m(e_x+e_z)\right]}{(1+m)(1-2m)}}$$

$$\boxed{\sigma_z = \frac{E\left[(1+m)e_z + m(e_x+e_y)\right]}{(1+m)(1-2m)}}$$

strain energy $= \frac{1}{2}(\sigma_x e_x + \sigma_y e_y + \sigma_z e_z) \times V$

$$= \frac{1}{2}\,\frac{E\left[(1-m)(e_x^2+e_y^2+e_z^2) + 2m(e_xe_y+e_ye_z+e_ze_x)\right]}{(1+m)(1-2m)}$$

— $$TdS = dU + PdV$$

Availability $= \Delta U - TdS + P_0 \Delta V$

→ For a given system of eqns

$\left[\begin{array}{ccc|c} - & - & - & - \\ - & - & - & - \end{array}\right]$, if we get $\left[\begin{array}{ccc|c} - & - & - & - \\ 0 & 0 & 0 & 0 \end{array}\right]$, the system has ∞ solns.

→ When one stress is larger than other two, the point is under uni axial loading and all failure theories are applicable.

→ Radial $acc^n = \omega^2 r$
Tangential $acc^n = \alpha r$

→ Kaplan $\boxed{Q = \frac{\pi}{4}(D^2 - d^2)\,\psi\sqrt{2gh}}$

ψ → flow ratio

$u = K\sqrt{2gh}$

K → speed ratio

→ MRR in ascending order LBM, EBM, USM, EDM, ECM

→ coefficient of volume expansion $= \boxed{\frac{1}{V}\frac{dV}{dT}}$

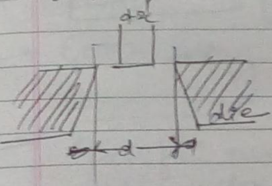
→ Flywheel
P = power
work done per cycle $= \frac{P}{N/60}$

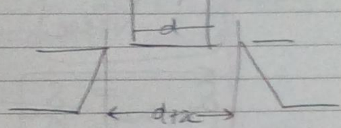
max fluctuation of energy $= \frac{P}{\frac{N}{60}} \times C_E$ (coeff of fluc of energy)

$\Delta E = U_0 = I\omega^2 C_s$

→ ~~Sheet~~ Blanking
cut out piece is desired

Piercing
cut out part is waste





→ Maximum clearance = UL of hole − LL of shaft
~~Minimum~~ allowance = LL of hole − UL of shaft
(with sign)

→ Extrusion —
K = extrusion ratio $= \frac{A_0}{A_f}$ → A_f = area of extruded part

strain $= \ln(K)$

extrusion ram pressure $= \sigma \ln(K)$

→ In stress-strain diagram, if an object is loaded ~~with~~ beyond its plastic limit, and then unloaded then, when it is loaded again, ~~the new~~ proportional ~~elastic~~ limit now will be till the previous stress point.

→ Structure

$\boxed{m = 2j - 3}$

m → no. of members
j → no. of joints

imperfect
perfect
redundant

→ Boundary Layer

$\boxed{\dfrac{\delta}{x} = \dfrac{5}{\sqrt{Re_x}}}$ $\boxed{C_{f_x} = \dfrac{0.664}{\sqrt{Re_x}}}$ $\boxed{\overline{C_f} = \dfrac{1.328}{\sqrt{Re}}}$

$\boxed{\delta_{thermal} = \dfrac{\delta}{\sqrt[3]{Pr}}}$

Laminar

$\boxed{h_x = 0.332\left(\dfrac{K}{x}\right)\sqrt{Re}\ \sqrt[3]{Pr}}$ $\boxed{\overline{h} = 0.664\left(\dfrac{K}{L}\right)\sqrt{Re}\ \sqrt[3]{Pr}}$

$\boxed{Nu_x = 0.332\ \sqrt{Re}\ \sqrt[3]{Pr}}$ $\boxed{\overline{Nu} = 0.664\ \sqrt{Re}\ \sqrt[3]{Pr}}$

Turbulent

$\boxed{h_x = 0.0288\left(\dfrac{K}{x}\right)(Re_x)^{4/5}(Pr)^{1/3}}$ $\boxed{\overline{h} = 0.036\left(\dfrac{K}{L}\right)Re^{4/5}\ Pr^{1/3}}$

$\boxed{Nu_x = 0.0288\ Re^{4/5}\ Pr^{1/3}}$ $\boxed{\overline{Nu} = 0.036\ Re^{4/5}\ Pr^{1/3}}$

$\boxed{\dfrac{\delta}{x} = \dfrac{0.371}{\sqrt[5]{Re}}}$ $\boxed{\dfrac{u}{U} = \left(\dfrac{y}{\delta}\right)^{1/7}}$

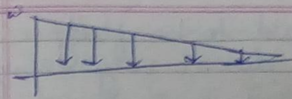
→ Poisson's Ratio = $\dfrac{\text{Lateral strain}}{\text{linear strain}}$

→ moment area method

$\boxed{\theta_{max} = \dfrac{A}{EI}}$ $\boxed{A \text{ of BMD}}$

$\overline{x}$ = distance of CG from left end

$\boxed{y_{max} = \dfrac{A\overline{x}}{EI}}$

→  $\boxed{y = \dfrac{wL^4}{30EI}}$

→ Strain energy caused by bending = $\int \dfrac{M^2 dx}{2EI}$

→ Euler's theory is NOT for eccentric loads.

→ $\boxed{\text{Specific modulus / specific stiffness} = \dfrac{E}{\rho}}$

→ yeild stress - max resistance to deformation per unit area

proof stress - allowable resistance to deformation per unit area

→ Stress Ratio - ratio of min stress to max stress.

→ $\tan x = x + \dfrac{x^3}{3} + \dfrac{2x^5}{15} + \dots$

→ Cauchy's Theorem

$\boxed{f(a) = \dfrac{1}{2\pi i}\int \dfrac{f(z)}{(z-a)}dz}$ $\boxed{f^n(a) = \dfrac{n!}{2\pi i}\int \dfrac{f(z)\,dz}{(z-a)^{n+1}}}$

Residue

$\boxed{\text{Res } f(a) = \lim_{z \to a}\left[(z-a)f(z)\right]}$ $\boxed{\text{Res } f(a) = \dfrac{1}{(n-1)!}\left[\dfrac{d^{n-1}}{dz^{n-1}}(z-a)^n f(z)\right]}$

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→ Velocity profile is said to be fully developed when it doesn't vary along the length of pipe.

→ uniform pressure theory (new clutch) $\boxed{R = \frac{2}{3}\left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right)}$

→ Bearing

loss of power - $P = T \times \omega$

$= F \times r \times \omega =$

$= [(\text{shear stress}) \times \text{area}] \times r\omega$

$= (\tau \times 2\pi r L) r\omega$

$= \left(\mu \frac{v}{y} 2\pi r L\right) r\omega = \left(\frac{\mu v}{c} \times 2\pi r L\right) \times r\omega$

$= \left[\frac{\mu (r\omega)}{c} 2\pi r L\right] \times r\omega$

$= \boxed{\frac{2\pi \mu r^3 L \omega^2}{c}}$

→ Mechanical Advantage $= \boxed{\frac{\text{output effort}}{\text{input effort}}}$

→ Turbine -

input pressure, vel given $E_1 = \frac{P}{\rho g} + \frac{V^2}{2g}$

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output pressure, vel given $E_2 = \frac{P}{\rho g} + \frac{V^2}{2g}$

head loss $= E_1 - E_2 = h_L$

Power produced $= \boxed{\rho g Q h_L}$

→ $\boxed{dQ = m C_p dT}$

$\boxed{dU = m C_v dT}$

→ $\boxed{L_{10} = \left(\frac{C}{P}\right)^p}$ $p = 3$ ball, $\left(p = \frac{10}{3}\right)$ $\boxed{L_{10} = \frac{60 n L_{10h}}{10^6}}$

$\boxed{\left(\frac{L}{L_{10}}\right) = \left[\frac{\ln(1/R)}{\ln(1/R_{90})}\right]^{1/1.17}}$

→ TRUSS

① Method of joints

⇒ Find reaction at base joints.

⇒ For a given joint, ~~find~~ resolve forces along horizontal or vertical dirⁿ to find remaining forces

② method of sections -

⇒ Find reaction at joints

⇒ Cut one section passing through some members. Select one side (left, say). Pick a point on right. For all the forces in left section, find their moments about a point on right & equate to zero

→ Soderberg

$$\boxed{\frac{\sigma_m}{S_{yt}} + \frac{\sigma_a}{S_e} = \frac{1}{fs}}$$

Goodman

$$\boxed{\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} = \frac{1}{fs}}$$

Gerber

$$\boxed{\left(\frac{\sigma_m}{S_{ut}}\right)^2 fs + \frac{\sigma_a}{S_e} = \frac{1}{fs}}$$

→ Recrystallisation temp
$\frac{2}{3} \to \frac{1}{2}$ of melting point

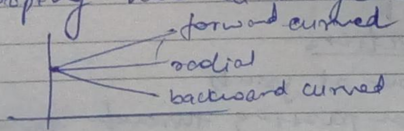
→ Ideal gas laws valid for gases low pressure and high temp.

→ For real ~~skew~~ symmetric matrix, eigen values are purely imaginary.

→ Coriolis component is present in shaper.

→ Eigen values of symmetric stress matrix are diagonal elements

→ Impeller with backward curved blades gives a drooping head-discharge characteristic.



→ $$\boxed{\frac{X_n}{X_{n+1}} = e^{\xi\omega_n t}}$$

→ Uniform distribution

$\boxed{\text{mean} = \frac{a+b}{2}}$ $\boxed{\text{variance} = \frac{(b-a)^2}{12}}$

→ Eulers theorem for homogeneous function

$$\boxed{x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} =} \; n\frac{f(u)}{f'(u)}$$

→ velocity $= \sqrt{V_r^2 + V_t^2} = \sqrt{V_r^2 + (r\omega)^2}$

→ When gears rotate, same power transmitted, torque may vary.

→ Slope of vaporization curve is always positive

→ $\boxed{E(x) = \int_{-\infty}^{\infty} x f(x)\,dx}$ $\boxed{E(x^2) = \int_{-\infty}^{\infty} x^2 f(x)\,dx}$

$Var(x) = E(x^2) - [E(x)]^2$

$\boxed{var(ax+b) = a^2\, var(x)}$

→ When 2 gears mesh,
① gear is subjected to axial, shear & bending stress
② gear shaft is subjected to horizontal & vertical bending moment and twisting

→ Shrinkage of weld joint

transverse unrestrained joint = $\boxed{\frac{1.52 \times D_f}{t}}$

length of fillet leg (D_f); plate thk (t)

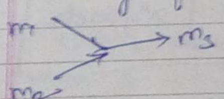
→ clearance per side = $\boxed{0.0032\, t\, \tau}$ for punching

Die dia = $\boxed{D + 2 \times C}$

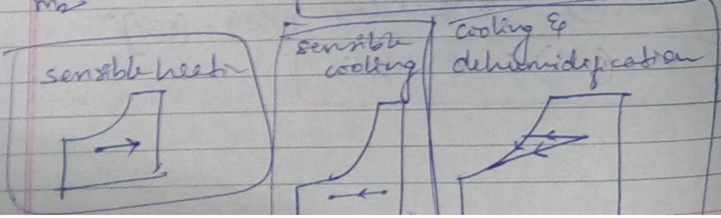
→ Displacement thickness = $\delta^* = \delta/3$
momentum thickness = $\theta = \delta/8$

→ clearance for shearing = $\boxed{0.0032\, t \sqrt{\tau}}$

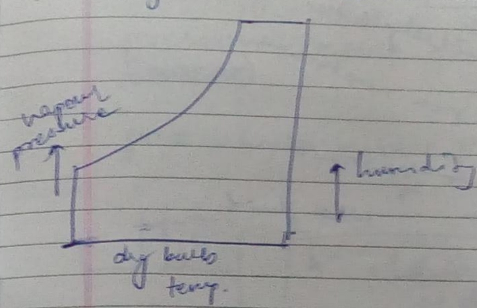
→ mixing of air streams



$$\boxed{\frac{m_1}{m_2} = \frac{\omega_3 - \omega_2}{\omega_1 - \omega_3} = \frac{h_3 - h_2}{h_1 - h_3}}$$



→ Psychrometric chart



→ $$\boxed{P_v = P_{vs} - \frac{[P_t - (P_{vs})_{wb}][t_{db} - t_{wb}]}{1527.4 - 1.3\, t_{wb}}}$$

→ $$\boxed{L[f(t)] = \int_0^\infty e^{-st} f(t)\, dt}$$

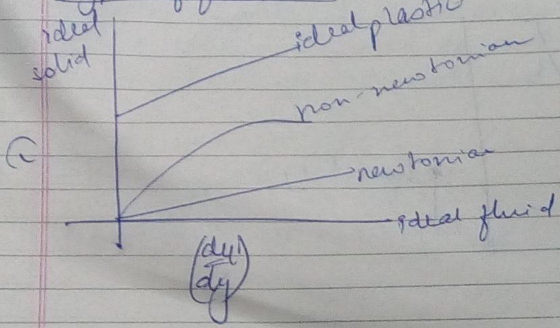
→ Press forging – ~~by~~ slowly applying a continuous pressure on face.

Upset forging – increases diameter of workpiece by compressing its length. Usually done with high speed machines using crank press.

→ Homogeneous function
$\phi(x, y) \rightarrow x^n \phi(y/x) \rightarrow$ homogeneous of degree n.

$$\boxed{x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = nu}$$

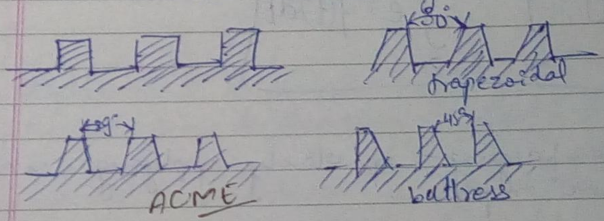
Types of fluids



Bolt Convention

M5 — nominal diameter = $\boxed{5\text{ mm}}$

ISO metric - thread angle = 60°



M 6X1 → $\boxed{\text{nominal dia : 6mm}}$ pitch = 1 mm

Froude's Number

$$\boxed{F_r = \frac{V}{\sqrt{gl}}}$$

V → velocity of flow

l → length of pipe

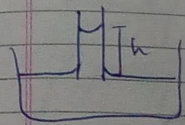
Capillarity

pressure inside a solid bubble (~~[illegible]~~) $p = \boxed{\frac{4\sigma}{d}}$

for a hollow bubble $p = \boxed{\frac{8\sigma}{d}}$

σ → surface tension

p ←



$$\boxed{h = \frac{4\sigma\cos\theta}{\rho g d}} \approx \boxed{\frac{4\sigma}{\rho g d}}$$

$\boxed{\theta \text{ for } Hg = 128^\circ}$ $\boxed{\theta_{H_2O} \approx 0}$

Matrix

symmetric $A = A^T$

skew-symmetric $\boxed{A = -A^T}$

idempotent $\boxed{A^2 = A}$

adjoint (A) = (matrix of co-factor of matrix A)^T

$$\boxed{A^{-1} = \frac{\text{adj } A}{|A|}}$$

→ Double-overhung turbine
develops power P.
power for each turbine $= P/2$

→ $N_S = \frac{N\sqrt{P}}{H^{5/4}}$ → power in kW

→ Brayton cycle

$$\boxed{r_{p_{max}} = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}}$$

→ $\boxed{V = C_v\sqrt{2gh}}$ $\boxed{u = \phi\sqrt{2gh} = \frac{\pi D N}{60}}$

→ Drawing -
length of job increased by decreasing its c/s area

↔ Upsetting -
length of metal is reduced while increasing the cross-sectional area →

→ Swaging -
hammering the metal stock while it is held on anvil with any one concave tools called swages.

→ Coining
closed die forging

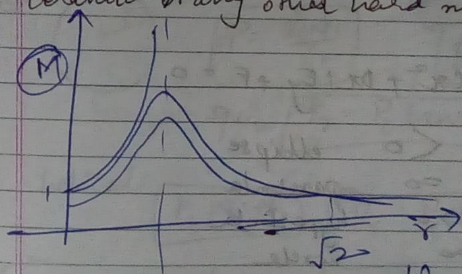
→ Fullering
Reduce dia & make it longer

→ Moody's formula

$$\left(\frac{1-\eta_{prototype}}{1-\eta_{model}}\right) = \left(\frac{D_m}{D_p}\right)^{\alpha}\left(\frac{H_m}{H_p}\right)^{\beta}$$

→ $\boxed{\eta = 1 - \frac{T_{min}}{T_{max}}\, r_p^{\frac{\gamma-1}{\gamma}}}$ $\boxed{\text{optimum } r_p = \left(\frac{T_3}{T_1}\right)^{\frac{\gamma}{2(\gamma-1)}}}$

→ Shot peening - producing compressive residual stress by bombarding metal with small spheres of ceramic or any other hard material. Prevents fatigue & stress corrosion failures.



$\frac{\omega}{\omega_n}$ reduces after $\sqrt{2}$.

→ Radiation shield

A_1, ϵ_1, T_1 | ϵ_3 | A_2, ϵ_2, T_2

without shield

$$\boxed{Q_{net} = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1\right)}}$$

with shield

$$\boxed{Q = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_3} - 1\right) + \left(\frac{1}{\epsilon_2} + \frac{1}{\epsilon_3} - 1\right)}}$$

$$\boxed{\epsilon_1 = \epsilon_2 = \epsilon_3 \quad T_3^4 = \frac{T_1^4 + T_2^4}{2}}$$

n shields

$$\boxed{Q = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\epsilon_A} + \frac{1}{\epsilon_B} + 2\sum \frac{1}{\epsilon_i} - (n+1)}}$$

→ Intensive prop → independent of mass content

point – pr / temp

path – heat / work

→ Conic

$$Ax^2 + Bxy + Cx^2 + Dx + Ey + F = 0$$

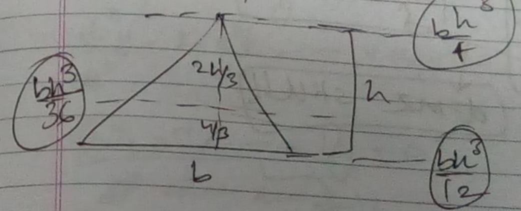
$B^2 - 4AC < 0$ ellipse

$B^2 - 4AC = 0$ parabola

$B^2 - 4AC > 0$ hyperbola

$A = C, B = 0$ circle

→ Moment of Inertia



→ section modulus

$\frac{\sigma}{y} = \frac{M}{I} \Rightarrow \boxed{\sigma = \frac{M}{(I/y)}}$ → section modulus

→ Polar modulus $= I_r / R$ $\boxed{I_r \text{ - polar moment of inertia}}$

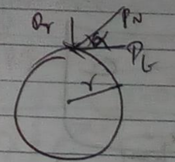
→ Gears

① Pressure angle (α)

② no of teeth to avoid interference

$$\boxed{Z = \frac{2}{\sin^2\alpha}}$$

③



$$\boxed{P = \frac{2\pi NT}{60}} \quad \boxed{P_t \times r = T}$$

spur $\boxed{P_r = P_t \tan\alpha}$

helical $\boxed{P_t \times r = M_t}$ $\boxed{P_r = P_t \frac{\tan\alpha}{\cos\psi}}$ ψ = helix angle

$$\boxed{\cos\psi = \frac{\tan\alpha_n}{\tan\alpha}}$$

$$\boxed{d = \frac{m_n z}{\cos\psi}} \quad \boxed{m_n = m\cos\psi}$$

$$\boxed{d = mz \text{ still!!}}$$

→ **Nozzles**

Exit velocity $= \boxed{44.72\sqrt{h_d}}$

Friction factor $= \boxed{44.72\sqrt{Kh_d}}$

$$\boxed{C = \sqrt{2\left(\frac{n}{n-1}\right) P_1 V_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]}}$$

$P_1V_1 \rightarrow P_2V_2$

$$\boxed{m = \frac{AC}{V_2}}$$

$$\boxed{\text{critical pressure ratio} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}}$$

→ **SFEE**

$$\boxed{u_1 + \frac{P}{\rho g} + \frac{V^2}{2g} + z + pV + Q = C}$$

u_1 → internal energy; z → height; pV → energy reqd for 1kg of fluid; Q → heat supplied

$$\boxed{\begin{aligned} \Delta h &= mc_p\,\Delta T \\ \Delta u &= mc_v\,\Delta T \end{aligned}}$$

→ complimentary function

$$\frac{d^n y}{dx^n} + K_1 \frac{d^{n-1} y}{dx^{n-1}} + \cdots + K_n y = 0$$

$$(D^n + D^{n-1} + \cdots + 1)y = 0$$

solve the eqn

(A) $(D - m_1)(D - m_2) \cdots (D - m_n) = 0$

$$\boxed{y = C_1 e^{m_1 x} + C_2 e^{m_2 x} + \cdots}$$

(B) $m_1 = m_2$

$$y = (C_1 + C_2 x)e^{mx}$$

(C) $m_{1,2} = \alpha \pm i\beta$

$$\boxed{y = C_1 e^{(\alpha+i\beta)x} + C_2 e^{(\alpha-i\beta)x} \cdots}$$

→ Particular Integral

for the given differential eqn

$$\boxed{PI = \left(\frac{1}{D^n + D^{n-1} + \cdots + k_n}\right) X}$$

(A) $X = e^{ax}$ $\quad \boxed{D^n e^{ax} = a^n e^{ax}}$ $\quad \boxed{\frac{1}{f(D)} e^{ax} = \frac{1}{f(a)} e^{ax}}$

(B) $X = \sin(ax+b)$ or $\cos(ax+b)$

$$\frac{1}{f(D^2)}\sin(ax+b) = \frac{1}{f(-a^2)}\sin(ax+b) \quad \text{if } f(-a^2) \neq 0$$

else $\frac{1}{f(D^2)}\sin(ax+b) = x\frac{1}{f'(-a^2)}\sin(ax+b) \quad$ if $f'(-a^2) \neq 0$

and so on. Add powers of x as well.

$$\boxed{d = \frac{m_n Z}{\cos\psi}}$$ $\boxed{m_n = m\cos\psi}$

$\boxed{d = mZ}$ still!!

→ Nozzles

Exit velocity $= 44.72\sqrt{h_d}$

Friction factor $= \boxed{44.72\sqrt{kh_d}}$

$$\boxed{C = \sqrt{2\left(\frac{n}{n-1}\right)p_1V_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]}}$$

$p_1V_1 \longrightarrow p_2V_2$

$$\boxed{m = \frac{AC}{V_2}}$$

$$\boxed{\text{critical pressure ratio} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}}$$

→ SFEE

$$\boxed{u_1 + \frac{P}{\rho g} + \frac{V^2}{2g} + z + pV + Q = C}$$

u_1: internal energy; z: height; pV: energy reqd for 1kg of fluid; Q: heat supplied

$$\boxed{\begin{aligned}\Delta h &= mc_p\Delta T\\ \Delta u &= mc_v\Delta T\end{aligned}}$$

→ Complimentary function

$$\frac{d^ny}{dx^n} + k_1\frac{d^{n-1}y}{dx^{n-1}} + \cdots + k_ny = 0$$

$$(D^n + D^{n-1} + \cdots + 1)y = 0$$

solve the eqn.

(A) $(D-m_1)(D-m_2)\cdots(D-m_n) = 0$

$$\boxed{y = C_1e^{m_1x} + C_2e^{m_2x} + \cdots}$$

(B) $m_1 = m_2$

$$y = (C_1 + C_2x)e^{mx}$$

(C) $\boxed{m_{1,2} = \alpha \pm i\beta}$

$$\boxed{y = C_1e^{(\alpha+i\beta)x} + C_2e^{(\alpha-i\beta)x} + \cdots}$$

→ Particular Integral

for the given differential eqn

$$\boxed{PI = \left(\frac{1}{D^n + D^{n-1} + \cdots + k_n}\right)X}$$

(A) $X = e^{ax}$ $\boxed{D^ne^{ax} = a^ne^{ax}}$ $\boxed{\frac{1}{f(D)}e^{ax} = \frac{1}{f(a)}e^{ax}}$

(B) $X = \sin(ax+b)$ or $\cos(ax+b)$

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else $\frac{1}{f(D^2)}\sin(ax+b) = x\frac{1}{f'(a^2)}\sin(ax+b)$ if $f'(-a^2) \neq 0$

and so on. Add powers of x as well.

(c) $X = x^m$

$$\frac{1}{f(D)} x^m = \left[f(D)\right]^{-1} x^m$$

expand $f(D)$ using binomial theorem and solve

(d) $X = e^{ax} V$ $\quad V = f(x)$

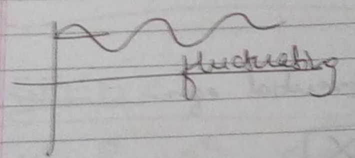
$$\frac{1}{f(D)}\left(e^{ax} V\right) = \boxed{e^{ax} \frac{1}{f(D+a)} V}$$

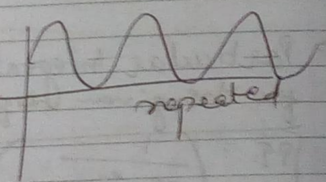
$$\frac{1}{f(D-a)^m} e^{ax} = \boxed{\frac{x^m}{m!} e^{ax}}$$

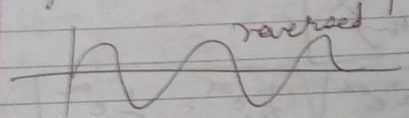
→ Rubbing velocity = (relative angular velocity) × (radius)

→ Entire function — fn that is analytic in a range

→





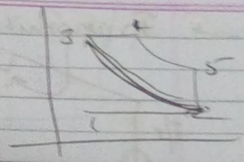


↑RRF

→ critical speed = $\sqrt{g/\Delta}$

critical speed is independent of eccentricity

→ diesel engine



compression ratio = V_3/V_2

expansion ratio = V_5/V_4

cut-off ratio = V_4/V_3

→ Powder metallurgy - Fe/ Al /Cu

→ $Q = A v$

Q = vol. flow rate

$\dot{m}$ = mass flow rate = ρQ

→ Auto-collimator - straightness

→ interferometry - flatness

→ Hobbing is the most accurate method for making gears

or maybe gear shaping with pinion cutter

→ decrement Ratio

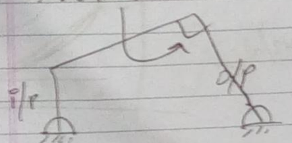
is not same as damping ratio

decrement ratio = $\frac{x_n}{x_{n+1}} = e^{\frac{2\pi\xi}{\sqrt{1-\xi^2}}}$

damping ratio = ξ

$(\frac{2}{3})^n \times \frac{2}{3}^n \; 10+\frac{1}{3}$

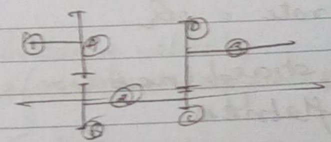
→ Transmission angle for 4 bar



→ Von mises theory of failure

$$\boxed{\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 + 3\tau_{xy}^2 - \sigma_x\sigma_y}}$$

→



net radial force acting on shaft ⓐ = sum of radial forces of on gear ⓑ + ⓒ.

→ Vibrations

n^{th} critical speed $\propto n^2$

n^{th} → $\boxed{\text{critical speed} = \frac{\text{frequency}}{(\text{no. of nodes})^2} \times n^2}$

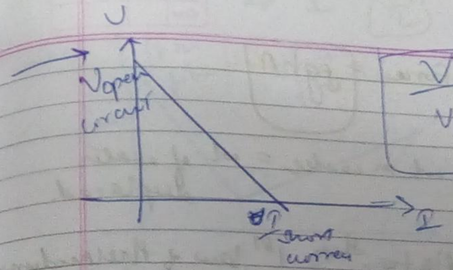
→ Torque required to lift a load

$$T = \frac{F d_m}{2}\left(\frac{l + \pi\mu d_m}{\pi d_m - \mu l}\right) + \frac{F \mu_c d_c}{2}$$

d_c → collar dia

d_m → $(d - p/2)$

l → np, p → pitch



$$\boxed{\frac{V}{V_{oc}} + \frac{I}{I_{sc}}}$$

→ $L\left[f^n(t)\right] = s^n F(s) - s^{n-1} f(0) - s^{n-2} f'(0) \cdots - f^{n-1}(0)$

→ $\boxed{W_{pump} = V\Delta P}$

→ DPT - temperature at which vapour condenses into liquid

→ Critical point - point at which no phase boundaries exist.
Usually known as the vapour-liquid critical point, above which, distinct liquid and gas phases did not exist.

Triple Point is that point where all three states exist at the same time.

Critical point specifies the condition at which there ~~is~~ ceases to be a boundary between the phases.

TP	all three states ~~are~~ are in equilibrium
CP	liquid and gas have the same density (vapour-liquid-CP)

→ ~~Eg~~ Buoyancy force = $\boxed{\rho g h A}$

wt in air - wt in water = wt of water displaced.

→ PMM ① - violate the 1st law of thermodynamics that would produce useful energy without any energy source or produce more energy than consumed.

PMM ② - violate 2nd law of thermodynamics produce useful energy from a single reservoir in equilibrium only

→ Properties of green sand -
① Porosity / Permeability $\boxed{\frac{501.26}{PL}}$ → mins.
② Plasticity
③ Adhesiveness
④ Cohesiveness
⑤ Refractoriness

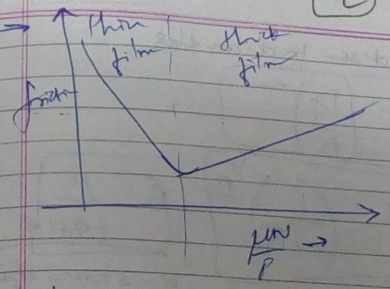
→ Auto-collimator - (straightness)
small angles with high sensitivity.

→ $V(x) = \alpha$
$\boxed{V(ax) = a^2 V(x)}$

→ $P(A/B) = \frac{P(A \cap B)}{P(B)}$

$P(\bar{A} \cap \bar{B}) = P(\overline{A \cup B}) = 1 - P(A \cup B)$

$\frac{\tau}{a} = \frac{T}{I_P} = \frac{G\theta}{L}$ $\boxed{\frac{C\theta}{L}}$



Friction circle radius = $r \times \mu$

→ If $1/m = 0$, it means that
material is rigid ✗
—"— perfectly plastic ✗
~~there~~ is no longitudinal strain in the material ✗

→ Stress concentration (K_t)
~~Kt~~ notch sensitivity $q = \frac{K_f - 1}{K_t - 1}$
K_f → actual stress concentration factor
K_t → theoretical stress concentration factor

$S_e = K_a K_b K_c K_d S_e'$ → endurance limit
K_a ↓ finish, K_b ↓ size, K_c ↓ reliability, K_d → $\frac{1}{K_f}$

→ if $|A| = 0$ eigen values of inverse don't exist

→ sagging (+) hogging (-)

→ $\boxed{0.45 \sqrt[3]{D} + 0.001 D}$

→ Maximum Reduction In diameter

$$\boxed{R = 1 - \left(\frac{D_f}{D_o}\right)^2}$$

$$\boxed{R = 1 - \left(\frac{1}{1+B}\right)^{1/B}} \qquad \boxed{B = \frac{\mu}{\tan\alpha}}$$

α = semi die angle

→ Strain energy $= \boxed{\frac{P\delta}{2}}$

→ max η of power transmission through pipes is $2/3$

→ $\boxed{HP = 745.6W}$

→ Grinding

Manufacturers code / Abrasive Chemical / Grain size / Grade / Structure / Bond / Suffix

→ An ~~other~~ expression $dP = Mdx + Ndy$ would be a thermodynamic property iff $\boxed{\left.\frac{\partial M}{\partial y}\right|_x = \left.\frac{\partial N}{\partial x}\right|_y}$

Chip Thickness Ratio = $\frac{\text{uncut chip thickness}}{\text{cut chip thickness}}$

→ Energy losses in Pipes

① enlargement = $\boxed{\frac{(V_1 - V_2)^2}{2g}}$

② contraction = $\boxed{\frac{0.5V^2}{2g}}$

③ entrace = $\boxed{\frac{0.5V^2}{2g}}$

④ exit = $\boxed{\frac{V^2}{2g}}$

⑤ gradual contraction / expansion = $\boxed{\frac{K(V_1 - V_2)^2}{2g}}$

⑥ bends = $\boxed{\frac{KV^2}{2g}}$

⑦ fittings = $\boxed{\frac{KV^2}{2g}}$

frictional loss = $\frac{4flV^2}{2gD}$

Hydraulic Grade line (HGL)
when a liquid flows through pipes encountering several losses in the way, and if we try to plot the pressure head at various places, we will get a straight line sloping downward throughout.

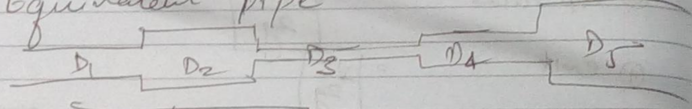
Total energy line (TEL)
line connecting the energy points from input to output.

Pipes in Series

Head losses are added linearly.

$$\boxed{H = \sum \frac{4flv^2}{2gD}} \rightarrow \text{(say, ignoring all others)}$$

Equivalent pipe



$$\boxed{\frac{L}{D^5} = \sum_{i=1} \frac{L_i}{D_i^5}}$$

Pipes in Parallel

$Q = Q_1 + Q_2$

Head loss is same $\boxed{h_f = \frac{f_1 l_1 v_1^2}{2gD_1} = \frac{f_2 l_2 v_2^2}{2gD_2}}$

→ ~~Governor~~

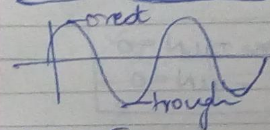
Heat Conduction in Sphere

$$\boxed{\frac{t - t_1}{t_2 - t_1} = \frac{r_2}{r}\left[\frac{r - r_1}{r_2 - r_1}\right]} \quad \boxed{Q = \frac{\Delta t}{\frac{(r_2 - r_1)}{4\pi k r_1 r_2}}} \quad \boxed{A_m = \frac{A_2 - A_1}{\ln(A_2/A_1)}}$$

Cylinder

$$Q = \frac{\Delta t}{\frac{\ln(r_2/r_1)}{2\pi k l}} \quad \boxed{\frac{t - t_1}{t_2 - t_1} = \frac{\ln(r/r_1)}{\ln(r_2/r_1)}} \quad \boxed{A_m = \sqrt{A_1 A_2}}$$

→ Vibration –



→ S-DOF

$m\ddot{x} + kx = 0$ $\quad x(t) = A\cos\omega_n t + B\sin\omega_n t$

$\boxed{\omega_n = \sqrt{\frac{K}{m}}}$ $\quad = A'\cos(\omega_n t - \phi)$

→ S-DOF damped (viscous)

$$\boxed{m\ddot{x} + c\dot{x} + kx = 0} \Rightarrow m\lambda^2 + c\lambda + k x = 0$$

$$x = C_1 e^{\lambda t} + C_2 e^{\lambda t}$$

$$\boxed{\lambda_{1,2} = \frac{-c \pm \sqrt{c^2 - 4mk}}{2m}} = \boxed{-\frac{c}{2m} \pm \sqrt{\frac{c^2}{4m^2} - \frac{k}{m}}}$$

$c^2 > 4mk \rightarrow$ no vibration

$c^2 = 4mk \rightarrow$ no vibration

$c^2 < 4mk$ – vibration

boundary condition $c^2 = 4mk \Rightarrow \boxed{c_c = 2\sqrt{mk}}$

$$\boxed{\text{Damping Ratio } \xi = \frac{c}{c_c}}$$

$$\boxed{x(t) = e^{-\xi\omega_n t}\left[\cos\omega_d t + B\sin\omega_d t\right]}$$

$$\boxed{\omega_d = \omega_n\sqrt{1 - \xi^2}}$$

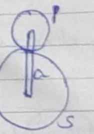
Energy loss per cycle $\propto$ (Amp loss)^2

$$\boxed{\frac{x_n}{x_{n+1}} = e^{\xi\omega_n \tau} = e^{\frac{2\pi\xi}{\sqrt{1-\xi^2}}}}$$

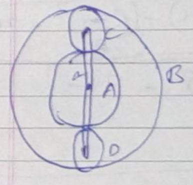
logarithmic decrement $\delta = \ln\left(\frac{x_n}{x_{n+1}}\right) = \frac{2\pi\xi}{\sqrt{1-\xi^2}}$

$\simeq \boxed{2\pi\xi} \; (\xi \ll 1)$

Epicyclic Gear Train



Rev (a)	Rev (S)	Rev (P)
0	1	$-T_S/T_P$
0	x	$-xT_S/T_P$
y	$y+x$	$y - x\cdot\frac{T_S}{T_P}$



$$T_B = 2\left[\frac{T_A}{2} + T_C\right]$$

a	A	C or D	B
0	1	$-T_A/T_C$	$-\frac{T_A}{T_C} \times \frac{T_C}{T_B}$
0	x	$-\frac{xT_A}{T_C}$	$-\frac{xT_A}{T_C} \times \frac{T_C}{T_B}$
y	$y+x$	$y - \frac{xT_A}{T_C}$	$y - \frac{xT_A}{T_B}$

Collision of 2 bodies

⇒ momentum is conserved.

⇒ $\boxed{e = \frac{\text{velocity of separation}}{\text{velocity of approach}}}$

Isochronism of Governer

- governer with range of speed zero is isochronous.

Flywheel -

coefficient of fluctuation of speed $= \frac{\text{change in speed}}{\text{mean speed}}$

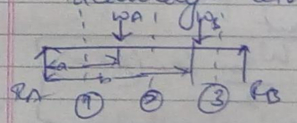
$$C_S = \boxed{\frac{v_1 - v_2}{\left(\frac{v_1 + v_2}{2}\right)}}$$

$$\boxed{U_0 = I\omega^2 C_S}$$

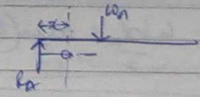
$$\boxed{\text{coeff of steadiness} = \frac{1}{C_S}}$$

$$\boxed{\text{coeff of fluctuation of energy} = \frac{\text{max fluctuation of energy}}{\text{work done per cycle}}}$$

Macaulays Method.

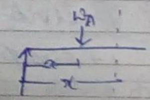


at ①



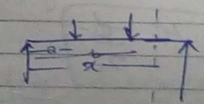
$M = R_A x$

at ②



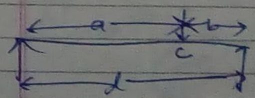
$M = R_A x - W_A(x-a)$

at ③



$M = R_A x - W_A(x-a) - W_B(x-b)$

$$\boxed{M = EI\frac{d^2y}{dx^2}}$$



$$\boxed{y_c = \frac{Wa^2b^2}{3EIl}}$$

$$y_{max} = y\left(\sqrt{\frac{l^2-b^2}{3}}\right) = \boxed{\frac{Wb(l^2-b^2)^{3/2}}{9\sqrt{3}\,EIl}}$$

→ Power Screws

$$\boxed{d_{mean} = d_{outer} - 0.5p}$$

Helix angle $= \alpha$

$$\boxed{\tan\alpha = \frac{l}{\pi d_m}}$$ → lead ⇒ dist the screw will move in one revolution

$$\boxed{\mu = \tan\phi}$$

Torque Requirement

Lifting load $= \boxed{M_t = \frac{W d_m}{2}\tan(\phi+\alpha)}$

Lowering load $= \boxed{M_t = \frac{W d_m}{2}\tan(\phi-\alpha)}$

$$\boxed{\eta = \frac{\tan\alpha}{\tan(\phi+\alpha)}} \quad \boxed{\eta_{max} = \frac{1-\sin\phi}{1+\sin\phi}}$$

η_{max} occurs at $\boxed{\alpha = 45 - \frac{\phi}{2}}$

η_{max} depends only on μ.

→ Radiation

✓ non-black planes

$Q_{1-2} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1}$ Total energy that leaves surface ① $= \boxed{Q_1 = \frac{\varepsilon_1\varepsilon_2}{\varepsilon_1+\varepsilon_2-\varepsilon_1\varepsilon_2}}$

Total energy that leaves surface ②

$$\boxed{Q_2 = \frac{\varepsilon_2\varepsilon_1}{\varepsilon_1+\varepsilon_2-\varepsilon_1\varepsilon_2}}$$

Energy going from ① - ② $= \boxed{Q_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)}}$

✓ non-black cylinders

$$\boxed{Q_1 = \frac{\varepsilon_1\varepsilon_2}{\frac{A_1}{A_2}\varepsilon_1 + \varepsilon_2 - \frac{A_1\varepsilon_1\varepsilon_2}{A_2}}} \quad \boxed{Q_2 = \frac{\varepsilon_2\varepsilon_1}{\varepsilon_2 + \frac{A_1}{A_2}\varepsilon_1 - \frac{A_1}{A_2}\varepsilon_1\varepsilon_2}}$$

Energy going from ① to ② $\boxed{Q_{12} = \frac{A_1\sigma_1(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2}-1\right)}}$

✓ 2 bodies in any configuration

① surface resistance — space resistance — surface resistance ②

$$\boxed{Q_{net} = \frac{E_{b_1} - E_{b_2}}{\left(\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{1-2}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}\right)}}$$

→ Brake Power

$$\frac{(W - S)\,\pi\,(D + t)\,N}{60}$$

W → dead load
S → spring balance
D → dia of pulley
t → rope thickness

→ For a Refrigerant R12 ⇒ R_{xy} ⇒ y = no. of fluorine molecules

→ $\boxed{h_f = \frac{fLV^2}{2gD}}$ $\boxed{\text{pressure loss} = \rho g h_f}$

→ Shafts

max principal stress theory

$$\boxed{\sigma = \frac{16}{\pi d^3}\left[M_b + \sqrt{M_b^2 + M_t^2}\right]}$$

max shear stress theory

$$\tau = \frac{16}{\pi d^3}\left[\sqrt{M_b^2 + M_t^2}\right]$$

→ $\boxed{\text{Sensible Heat Factor (SHF)} = \frac{\text{sensible}}{\text{sensible + Latent}}}$

→ ← C > 0.8 > C –

Hypo-eutectoid   eutectoid   Hyper-eutectoid

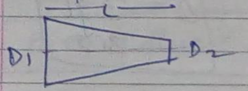
→ Molecular wt = $\frac{\sum (\%\text{ of a component})(\text{mol wt of that component})}{(\text{total }\%)}$.

→ Spectral Matrix is the one that consists of the eigen values in its principal diagonal.

→ interference $\tan\theta = \frac{n\lambda}{2xy}$

$n\lambda$ → micrometer
y → micrometer

→ Pipe of Varying Diameter



$$\boxed{\Delta p = \frac{128\,\mu Q L}{3\pi(D_1 - D_2)}\left[\frac{1}{D_1^3} - \frac{1}{D_2^3}\right]}$$

→ Pump $\boxed{\cancel{Q \propto N}}$ $\boxed{HP \propto d^3}$ $\boxed{\frac{H}{N^2D^2} = \text{const}}$

→ Radiation emitted = $\boxed{\sigma A T^4}$

σ → 5.67×10^{-8} W/m²K

→ Extrusion force = F = $A_o K \ln\left(\frac{A_o}{A_f}\right)$

A_o → billet area
K → extrusion constant
A_f → extruded part area

→ Poisson Distribution

very rare events but have a large no. of opportunities of occurrence

$$p(r) = \frac{m^r}{r!} e^{-m}$$

prob. of r successes

$m = np$ (mean; n = no. of trials, p = prob. of success)

$\boxed{\text{mean} = m \quad SD = \sqrt{m}}$ $\boxed{\mu_2 = m}$ $\boxed{\mu_3 = m + 3m^2}$

$\boxed{\text{skewness } \beta_1 = \frac{1}{m}}$ $\boxed{\text{kurtosis } \beta_2 = 3 + \frac{1}{m}}$

→ Normal Distribution

$$\boxed{f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}} \quad \boxed{z = \frac{x-\mu}{\sigma}}$$

→ Moment about $\bar{x}$

$$\boxed{\mu_r = \frac{1}{N} \Sigma f_i (x_i - \bar{x})^r}$$

$$\boxed{\text{skewness } \gamma_1 = \sqrt{\beta_1} = \sqrt{\frac{\mu_3^2}{\mu_2^3}}}$$

$$\boxed{\text{kurtosis } \beta_2 = \frac{\mu_4^2}{\mu_2^2}}$$

→ Correlation

coeff of correlation $\boxed{r = \frac{\Sigma XY}{n \sigma_x \sigma_y}}$

$X = x - \bar{x}$

$Y = y - \bar{y}$

σ_x = SD of x-series

σ_y = SD of y-series

LOR

$$\boxed{y - \bar{y} = r\frac{\sigma_y}{\sigma_x}(x - \bar{x})} \quad \boxed{x - \bar{x} = r\frac{\sigma_y}{\sigma_x}(y - \bar{y})}$$

y-on-x (regression coefficient) y on x

→ Continuous Probability Distribution

$$\boxed{\text{cumulative Prob. Dist} = \int_{-\infty}^{x} f(x)\,dx}$$

$$\boxed{\text{Expectation } E(x) = \int_{-\infty}^{\infty} x f(x)\,dx} \text{ or } \int_{-\infty}^{\infty} \phi(x) f(x)\,dx$$

($\phi(x)$: fn; $f(x)$: prob of the fn)

$$\boxed{\text{variance } \sigma^2 = \int_{-\infty}^{\infty} (x-\mu)^2 f(x)\,dx}$$

Variance $V(x) = E(x^2) - (E(x))^2$

$E(x) = \Sigma x p_i$

$E(x^2) = \Sigma x^2 p_i$

$V(x) = E(x^2) - (E(x))^2$

→ Order of error in Simpsons rule is $\propto h^2$.

→ Stalling of blades - air stream not able to follow the blade contour.

→ Knocking

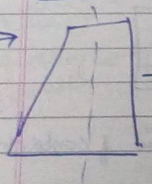
→ min speed for starting a centrifugal pump

$$\boxed{N = \frac{120\,\eta_{man}\,V_{w_2}\,D_2}{\pi(D_2^2 - D_1^2)}}$$

→ Specific speed of a pump (N_s)

$$\boxed{N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}}$$

→ $\boxed{\frac{N\sqrt{Q}}{H_m^{3/4}} = C}$ $\boxed{\frac{\sqrt{H_m}}{DN} = C}$ $\boxed{\frac{Q}{D^3N} = C}$ $\boxed{\frac{P}{D^5N^3} = C}$

→ 

Draft tube
→ apply bernoulli's eqn on both sections

→ Pressure drop in venturi and orifice $\propto$ (coefficient of discharge)^2

→ Designation of Refrigeration

$C_r H_s F_t Cl_y$

$s + t + y = 2r + 2$ | $s + t + y = 2r$

R $(r-1)(s+1)t$ | R1 $(r-1)(s-1)t$

→ <u>Nozzles</u>

exit velocity $= c = \sqrt{2\Delta h} = 44.72\sqrt{K\,\Delta h}$ (in kJ)

friction factor

→ Knocking - / Detonation / Pinking -
burning of fuel in one more pockets inside the cylinder apart from the usual shock wave set by the spark plug.

Prevention -
① fuel of high octane rating to be used
② increase air-fuel ratio
③ reduce load on engine

→ Pre-ignition
Ignition of fuel before sparking. Results from a hot-spot in the cylinder or too great a compression ratio for fuel.

LBT

→ ~~Vibration~~
Reaction Turbine
Degree of Reaction

$$= \frac{\Delta h_{rotor}}{\Delta h_{rotor} + \Delta h_{stator}}$$

→ Centrifugal tension
$= \frac{T_{tight\ side}}{3}$ for max power transmission

→ Isothermal → $\int p\,dv$ $-\int v\,dp$

→ Critical thickness of Insulation
$= \frac{K}{h}$ or $\frac{2K}{h}$. This formula gives thickness from center of pipe.

→ Whirling of shafts

additional defl^n of rotor due to centrifugal force $y = \dfrac{e}{\left(\frac{\omega}{\omega_c}\right)^2 - 1}$

e → eccentricity of mass

ω → frequency of revolution

ω_c → critical frequency

→ Gibbs Phase Rule

$$F + P - C = 2$$

F → degree of freedom
P → phase
C → no. of components

→ LMTD
when $\theta_1 = \theta_2$, LMTD $= \theta_1 = \theta_2 = \theta$ (itself)

→ 6×19 rope means
6 strands of 19 wires each

→ Elements — Attributes
$\bar{x}$, R — p, np, c, μ

→ Best size wire $\boxed{d = \frac{Pitch}{2} \sec\left(\frac{\theta}{2}\right)}$

→ Springs

$\boxed{\text{spring index} = D/d = \frac{\text{mean diameter}}{\text{dia. of wire}}}$

$\boxed{\text{pitch of coil} = \frac{\text{free length}}{n_t - 1}}$

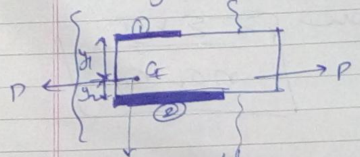
$\boxed{\tau = \frac{8PD}{\pi d^3}}$ $\boxed{K = \frac{Gd^4}{8D^3N}}$ $\boxed{\delta = \frac{8PD^3N}{Gd^4}}$

$\boxed{\theta = \frac{16PD^2N}{Gd^4}}$ $\boxed{\text{strain energy} = \frac{P\delta}{2}}$

→ n_1 & n_2 discs of multiple clutch, no of contact pairs are $n_1 + n_2 - 1$.

→ Critical pressure ratio for max discharge through a nozzle $= \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$

→ Axially Loaded Unsymmetrical Welded Joints



COG of 2 welds

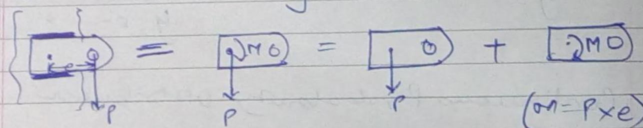
P_1 = strength of ①

P_2 = str. of ②

$\boxed{P_1 y_1 = P_2 y_2}$ $\boxed{l_1 y_1 = l_2 y_2}$

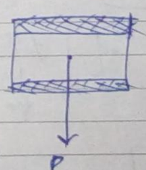
$\boxed{l_1 + l_2 = l}$ $\boxed{P = P_1 + P_2}$

→ Eccentric loading in Plane of weld



$(M = P \times e)$

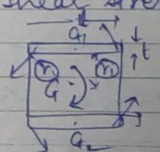
primary shear stress - due to force P



$\boxed{\sigma = P/A}$ $\boxed{A = A_1 + A_2}$ of both welds

secondary shear stress

$\tau_2 = \frac{Mr}{J}$



$\boxed{J_{G_1} = \frac{tl^3}{12}}$ $\boxed{= \frac{Al^2}{12}}$

$\boxed{J_G = J_{G_1} + A r_1^2}$

similarly find J_G for all welds.

$\boxed{\tau = \frac{Mr}{\Sigma J}}$

→ Thick shells

internal pr. | ext.

$\boxed{\sigma_r = -\frac{P_i D_i^2}{(D_o^2 - D_i^2)}\left[\frac{D_o^2}{4r^2} - 1\right]}$ $\boxed{\sigma_r = -\frac{P_o D_o^2}{(D_o^2 - D_i^2)}\left[1 - \frac{D_i^2}{4r^2}\right]}$

$\boxed{\sigma_t = \frac{P_i D_i^2}{(D_o^2 - D_i^2)}\left[\frac{D_o^2}{4r^2} + 1\right]}$ $\boxed{\sigma_t = -\frac{P_o D_o^2}{(D_o^2 - D_i^2)}\left[1 - \frac{D_i^2}{4r^2}\right]}$

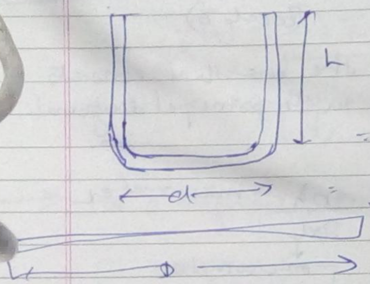
$\boxed{\sigma_l = -\frac{P_i D_i^2}{(D_o^2 - D_i^2)}}$

$t = \frac{D_i}{2}\left[\sqrt{\frac{\sigma_t + P_i}{\sigma_t - P_i}} - 1\right]$ Lame's

$t = \frac{D_i}{2}\left[\sqrt{\frac{\sigma + (1-2\mu)P}{\sigma - (1+\mu)P}} - 1\right]$ Clavarino

$\boxed{t = \frac{D_i}{2}\left[\sqrt{\frac{\sigma + (1-\mu)P}{\sigma - (1+\mu)P}} - 1\right]}$

→ Blank size



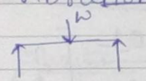
$D = \sqrt{d^2 + 4dh}$ $\left(\frac{d}{r} \geq 20\right)$

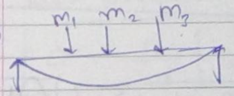
$= \sqrt{d^2 + 4dh - 0.5r}$ $\left(15 \leq \frac{d}{r} \leq 20\right)$

$= \sqrt{d^2 + 4dh - r}$ $\left(10 \leq \frac{d}{r} \leq 15\right)$

$= \sqrt{(d-2r)^2 + 4d(h-r) + 2\pi r(d - 0.7r)}$ $\left(\frac{d}{r} \leq 10\right)$

→ Vibrations

①  $f_n = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}}$ $\boxed{\delta = \frac{mgl^3}{3EI}}$

②  $\boxed{f_n = \frac{0.4985}{\sqrt{\delta_1 + \delta_2 + \dots + \frac{\delta_s}{1.27}}}}$

→ Average of a qty from 0 to x

$= \boxed{\frac{1}{x}\int_0^x f(x)\,dx}$ where $f(x)$ is local/instantaneous value

→ Stresses

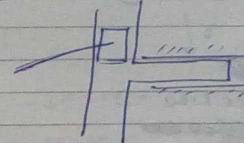
⇒ gradual load $\sigma = \frac{W}{A}$

⇒ suddenly applied load $= \frac{2W}{A} = \sigma$

⇒ impact load $\sigma = \frac{W}{A}\left[1 + \sqrt{1 + \frac{2hAE}{WL}}\right]$

→ Loss of head in "pipes"

$\frac{\Delta p}{\rho g} = \boxed{\frac{32\mu \bar{u} L}{\rho g D^2}}$

→ Scotch yoke  generates sine function

→ Kaplan

$\boxed{Q = \frac{\pi}{4}(D_o^2 - D_b^2) V_{f_1}}$ $\boxed{u_1 = u_2 = \frac{\pi D_o N}{60}}$

$\boxed{\text{Area of flow} = \frac{\pi}{4}(D_o^2 - D_b^2)}$

→ Probability

Baye's Thm $\boxed{P(A/B) = \frac{P(A)\,P\left(\frac{B}{A}\right)}{\sum P(A)\,P\left(\frac{B}{A}\right)}}$

A/B = A such that B has already happened.

Bernoulli Trials

$\boxed{p = \text{probability of success}}$ $\boxed{q = 1 - p}$

probability of r successes out of n-trial $= \boxed{{}^nC_r\, p^r q^{n-r}}$

$\boxed{\mu_2 = npq}$ $\boxed{\mu_3 = npq(p-q)}$ $\boxed{\mu_4 = npq[1 + 3(n-2)pq]}$

$\boxed{\beta_1 = \frac{\mu_3^2}{\mu_2^3}}$ $\boxed{\beta_2 = \frac{\mu_4}{\mu_2^2}}$ $\boxed{\text{skewness} = \frac{1-2p}{\sqrt{npq}}}$

kurtosis $= \beta_2$

$$\boxed{X = \frac{F_o/K}{\sqrt{(2\xi r)^2 + (1-r^2)^2}}}$$

$$\boxed{r_{peak} = \sqrt{1-2\xi^2}}$$

→ Viscous flow between 2 concentric pipes

$$\tau = \left(\frac{-\partial p}{\partial r}\right)\left(\frac{r}{2}\right)$$

$$u = \left(\frac{-\partial p}{\partial r}\right)\left(\frac{R^2-r^2}{4\mu}\right)$$

$$\bar{u} = \left(\frac{-\partial p}{\partial r}\right)\left(\frac{R^2}{8\mu}\right)$$

$$\boxed{\Delta p = \frac{32\mu \bar{u} L}{D^2}}$$

u_{max} occurs at $r=0$

$$\boxed{\frac{u_{max}}{\bar{u}} = 2}$$

Viscous flow between 2 parallel plates

$$u = \left(\frac{-\partial p}{\partial x}\right)\frac{(ty-y^2)}{2\mu}$$

$$\tau = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{t-2y}{2}\right)$$

$$\bar{u} = \left(\frac{-\partial p}{\partial x}\right)\left(\frac{t^2}{12\mu}\right)$$

$$\boxed{\frac{\partial p}{\partial x} = \frac{\partial \tau}{\partial y}}$$

$$\boxed{\frac{u_{max}}{\bar{u}} = \frac{3}{2}}$$

$$\boxed{\Delta p = \frac{128\mu Q L}{3\pi (R_1 - R_2)}\left[\frac{1}{D_1^3} - \frac{1}{D_2^3}\right]}$$

→ Cylinder with heat generation

t_a, t_w, q_g

$$\boxed{\frac{t - t_w}{t_{max} - t_w} = 1 - \left(\frac{r}{R}\right)^2}$$

$$\boxed{t = t_w + \frac{q_g}{4K}\left[R^2 - r^2\right]}$$

Energy generated per unit time within the rod = energy dissipated per unit volume, at the surface

$$\boxed{(q_g)(\pi R^2 L) = (h)(2\pi r L)(t_w - t_a)}$$

$$\boxed{t = t_a + \frac{q_g}{2h} R + \frac{q_g}{4K}\left[R^2 - r^2\right]}$$

$$t = t_w + \frac{q_g}{4K}\left[R^2 - r^2\right]$$

→ Heat Generation within a slab

same temp on both sides

$$t = \frac{q_g}{2K}(2L - x)\,x + t_w \qquad \left[t_{max} \text{ at } L/2\right]$$

different temp on both sides

$$t = \left[\frac{q_g}{2K}(L-x) + \frac{t_{w_2} - t_{w_1}}{L}\right]x + t_{w_1}$$

→ Coriolis Component of Acceleration

$= \boxed{2\omega V}$

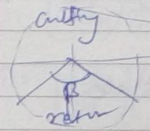
→ Gyroscope

An object rotating about an axis — this axis rotating about another axis perpendicular to it — as a result, the entire setup will rotate about an axis $\perp^r$ to both of them.

$\boxed{\alpha = \omega\omega_p}$ $\boxed{T = I\alpha}$

Plane viewed from backside –
Propellers rotating in clockwise sense, plane takes a left turn, its nose will go up and tail will go down.

→ Quick Return mechanism



$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360-\beta}{\beta}$$

→ $$\begin{bmatrix} \tau_{xy} & + & - \\ - & 0 & -\tau_{xy} \end{bmatrix} \begin{bmatrix} \sin 2\theta \\ 1 \\ \cos 2\theta \end{bmatrix} = \begin{bmatrix} \sigma_n \\ \tau \end{bmatrix}$$

→ No. of Instantaneous Centers

$= N = \frac{n(n-1)}{2}$ n = no. of links

Kennedy's Theorem – if three bodies have relative motion among themselves their I centers must lie on a straight line.

List ①	List ②
Brinell	Tungsten Carbide Ball
Vickers	Diamond pyramid
Rockwell	Diamond cone
Scleroscope	Diamond tipped hammer

→ Statistical Considerations In Design

$$\boxed{\hat{\sigma} = \sqrt{\frac{\frac{\Sigma f_i x_i^2}{n} - \left(\frac{\Sigma f_i x_i}{n}\right)^2}{N-1}}}$$

$$\boxed{z = \frac{x-\mu}{\sigma}}$$

→ Time taken to fill a mold

$$\boxed{= \frac{\text{Volume}}{A_{gate}\sqrt{2gH}}}$$

→ $\boxed{L\left[e^{at} f(t)\right] = f(s-a)}$

$$\boxed{L\left[t^n f(t)\right] = (-1)^n \frac{d^n}{ds^n}\left[f(s)\right]}$$

$$\boxed{L\left[f(t)\right] = \int_0^\infty e^{-st} f(t)\,dt}$$